VOLUME 62 [W.B. No. 1121] NUMBER 1

MONTHLY WEATHER REVIEW

JANUARY 1934

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UNITED STATES DEPARTMENT OF AGRICULTURE

WEATHER BUREAU

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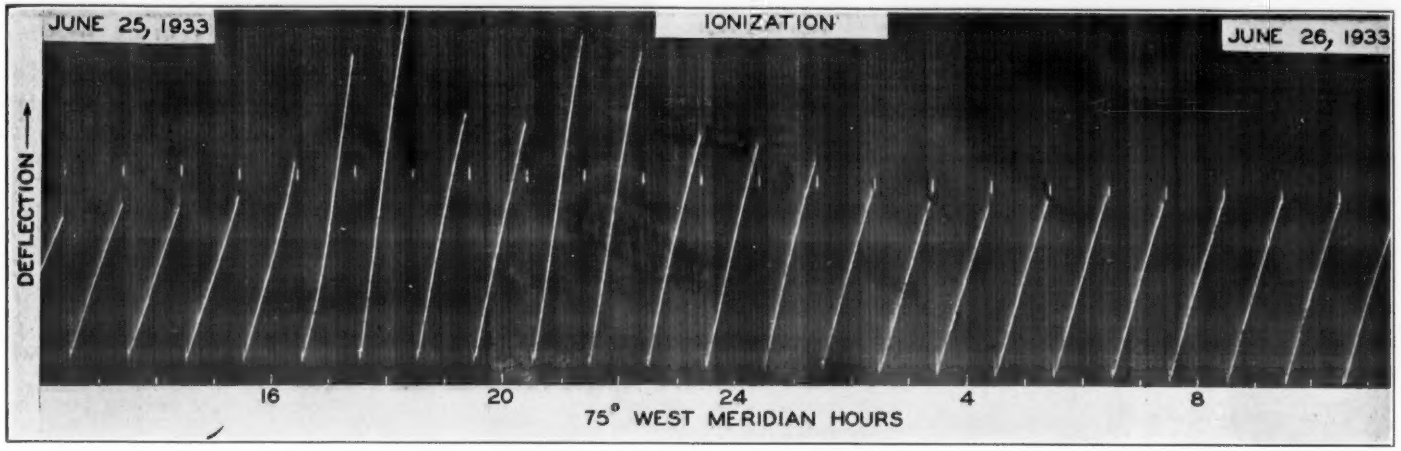

FIGURE 2a.—Ionization record, Washington, D.C., June 25–26, 1933.

MONTHLY WEATHER REVIEW

Editor, W. J. HUMPHREYS

VOL. 62, No. 1
W.B. No. 1121

JANUARY 1934

CLOSED MARCH 3, 1934
ISSUED APRIL 24, 1934

ATMOSPHERIC IONIZATION NEAR THE GROUND DURING THUNDERSTORMS

By G. R. WAIT and A. G. MCNISH

[Department of Terrestrial Magnetism, Carnegie Institution of Washington]

The effects described in this paper were observed while investigating the diurnal variation of small-ion formation in the lower atmosphere. The observing station was on the grounds of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, situated in the more sparsely settled portion of the northwestern section of the District of Columbia.

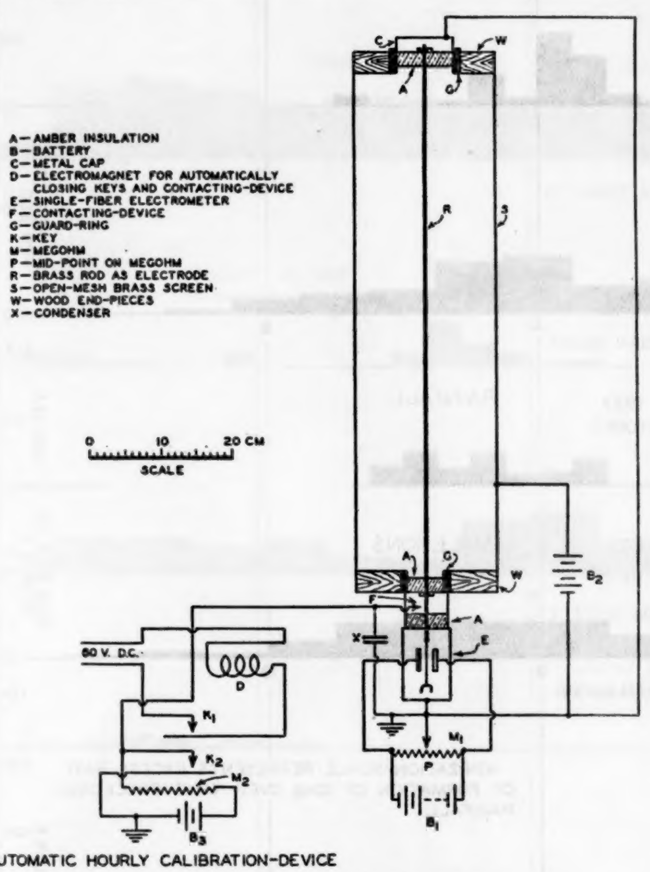

FIGURE 1.—Device for measuring total ionization in atmosphere.

The apparatus used is diagrammatically shown in figure 1. Ions are formed inside an airtight chamber by radiations which penetrate its wall. The chamber consists of a brass screen in the form of a cylinder, covered with thin cellophane. An electric field, maintained between an insulated concentric brass rod and the screen, causes the collection of ions of one sign on the rod. An electrometer connected to the rod measures the accumulated charge, thus indicating the rate at which the ions are formed inside the cylinder. The accumulation of charge is allowed to continue for 54 minutes, after which the rod is discharged, the electrometer calibrated, and the accumulation of charge resumed at the end of 60 minutes, the entire process being automatic. The deflections of the electrometer, directly proportional to the ionization, are recorded on photographic paper attached to a rotating drum. A reproduction of the record for one 24-hour interval, during which a thunderstorm occurred, is shown in figure 2*a*, in which the deflection at 8 hours corresponds to the production of 6.5 pairs of ions per second per cubic centimeter. A copy of the rain record for the same interval is shown in figure 2*b*.

In addition to diurnal and sporadic variations in the rate of ion formation in the closed vessel, a large increase in the rate of formation was observed to occur during thunderstorms and the few hours following them. This phenomenon is evidenced by figures 3*a* and 3*b*, showing the rainfall during half-hour intervals and the average increased rate of ion formation over corresponding hour intervals for several days during June to August 1933; the base values for the ionization are the mean ionization rates for the 3-hour interval preceding the rain. The salient features shown by figures 3*a* and 3*b* are: (1) The ionization increases as soon as the rain has begun to fall; (2) the effect persists for several hours after the rain has ceased; and (3) the effect is roughly proportional to the amount of rain which has fallen. During the heavy rain associated with the hurricane which occurred at Washington during the latter part of August, no appreciable increase in the rate of ion formation occurred, at least not before the heavy winds damaged the apparatus. It may be remarked that, during the period of recording, no thunderstorm occurred without abnormally high ionization; the ionization was abnormally high only once when there was no thunderstorm and in this case there was a heavy fog.

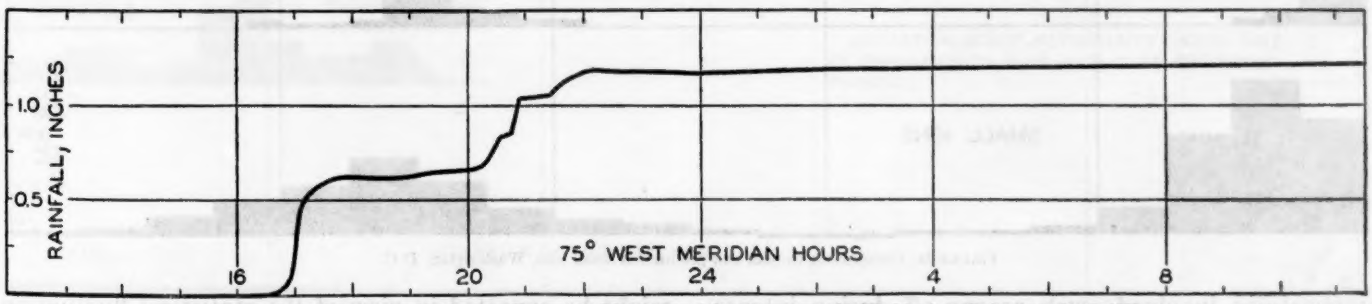

FIGURE 2*b*. Rainfall, Department of Terrestrial Magnetism, laboratory grounds, Washington, D.C., June 25-26, 1933.

In figure 4 the total rainfall during each storm is coordinated with the accumulated excess of ion formation during that storm. The degree of the proportionality is quite fair, particularly when consideration is given to the complications involved, such as run-off during intense showers and absorption of the rain by the ground.

The decay of the rate of ion formation after the rain has ceased for the several heavier showers is represented by figure 5. A curve of the equation $I = I_0 e^{-\lambda t}$ fitted to the data by least squares gives a value of 1.088 per hour for λ. A curve drawn for $\lambda = 1.548$ per hour, which is the constant for radium *B*, fits the data quite as well as might be expected in view of the statistical fluctuations involved.

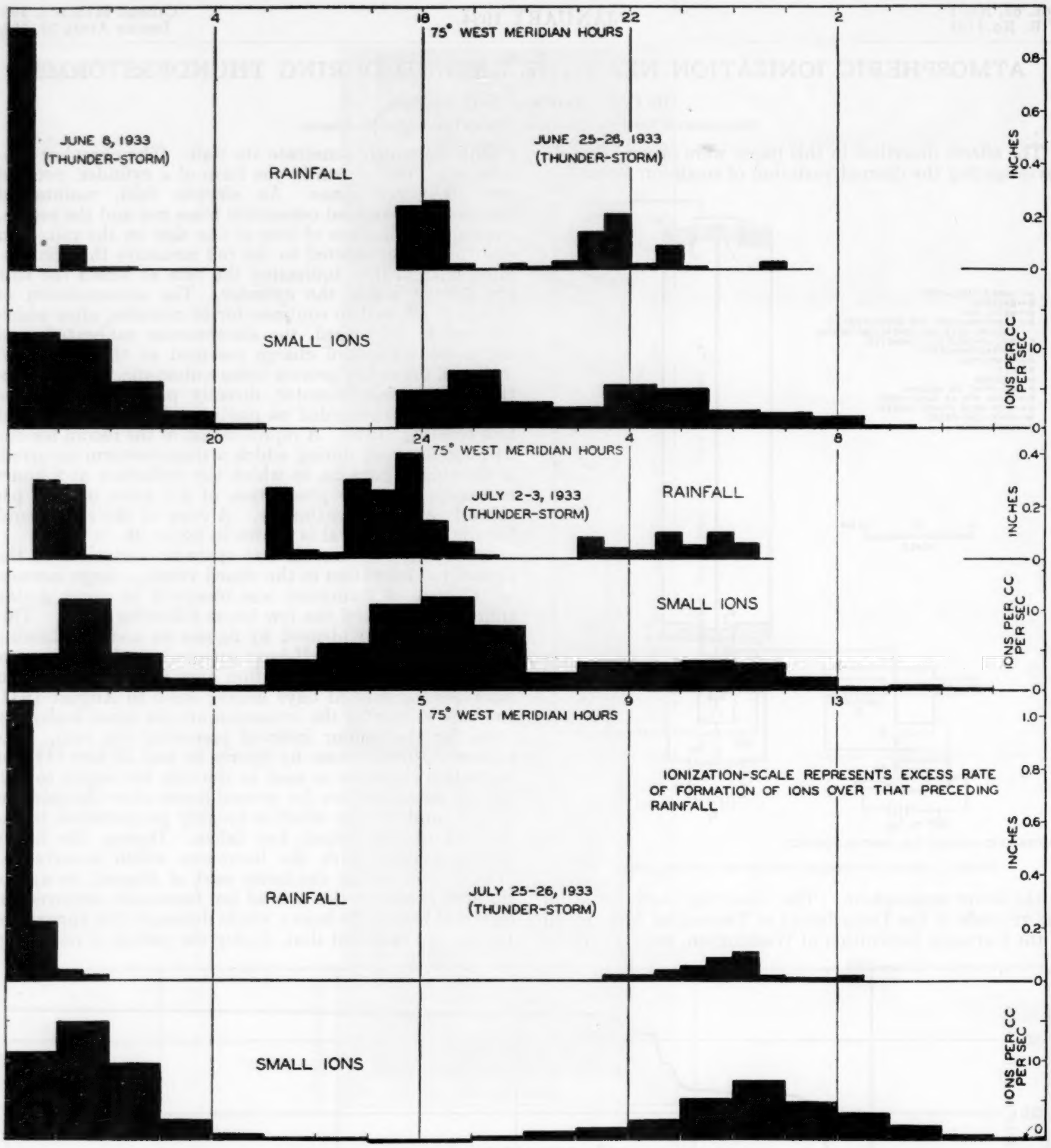

FIGURE 3a. Comparison rainfall and production small ions, Washington, D.C.

Apparently the explanation of this phenomenon is that the decay products of radium, principally radium *B* and

C in equilibrium with it, are carried to earth with the rain and in their disintegration produce the ionization. Radium emanation, if it is present in the falling rain, does not contribute to the ionization within the chamber, nor does it control the rate of decay of radium *B* and radium *C* present, to any appreciable extent, as evidenced by the rapidity of the decay, since the half-period for radium emanation is nearly 4 days. This cannot be adduced as proof of the absence of appreciable quantities of radium emanation in rain because radium emanation if carried by the rain might be quickly dissipated upon evaporation or absorption of the rain. Furthermore, although radium emanation is a powerful producer of ions, it would not produce many in the ionization chamber because it gives off only alpha particles which would not penetrate the walls of the chamber unless the disintegration which gives rise to them occurs within a few centimeters of the chamber, and then only a short portion of their effective paths would be inside the chamber.

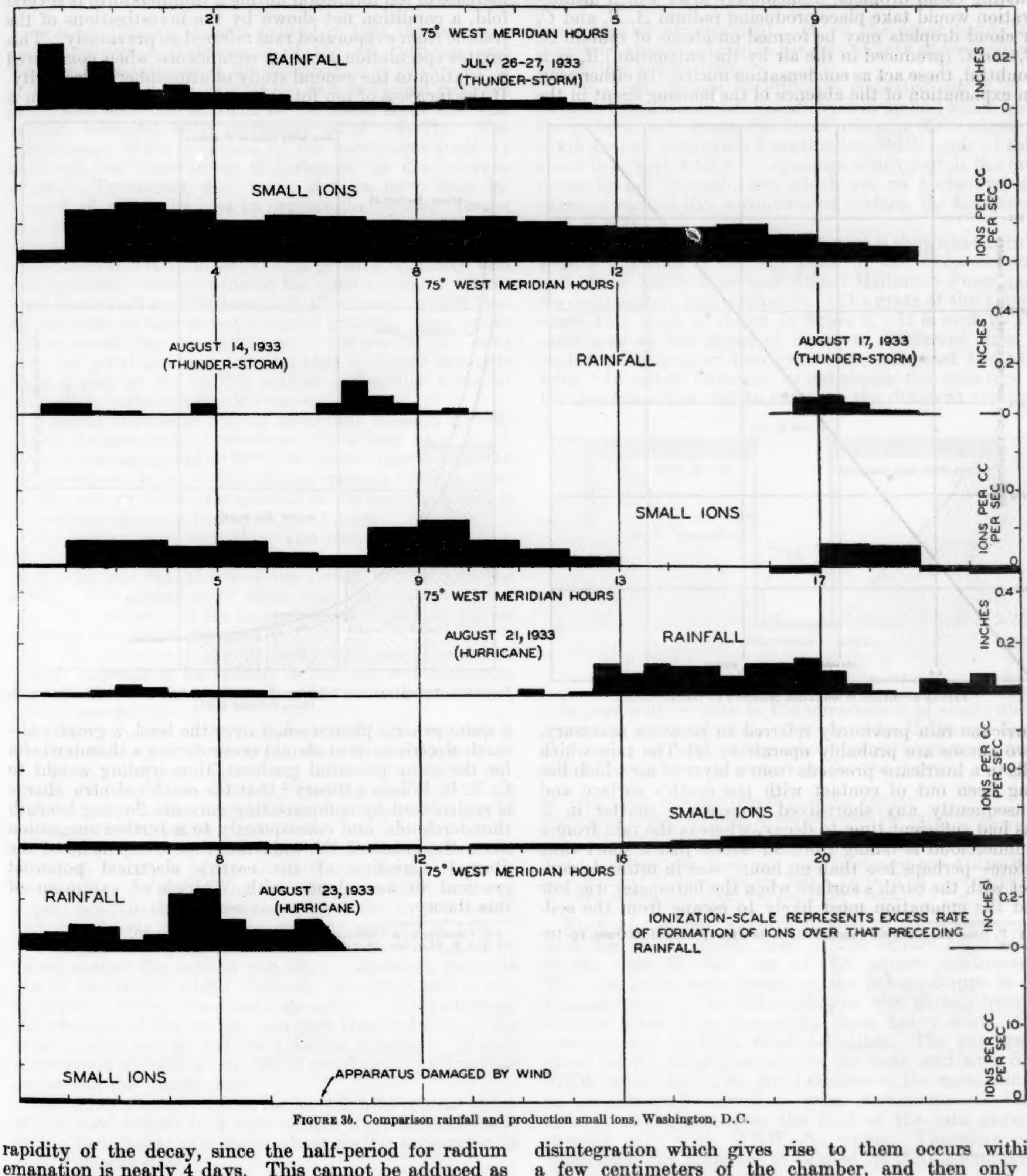

FIGURE 3b. Comparison rainfall and production small ions, Washington, D.C.

Although the presence of radioactive substances in precipitation has long been known through the radioactivity of the residue left after evaporation,[1] the observations cited above yield an interesting insight into the problem. Undoubtedly radium emanation, escaping from the soil, is carried up into the air. There it may be dissolved in existing cloud droplets, immediately after which disintegration would take place producing radium *A*, *B*, and *C*; or cloud droplets may be formed on atoms of radium *A*, *B*, and *C* (produced in the air by the emanation) if, as is doubtful, these act as condensation nuclei. In either case, an explanation of the absence of the ionizing agent in the hurricane rain previously referred to becomes necessary. Two causes are probably operative: (*a*) The rain which falls in a hurricane proceeds from a layer of air which has long been out of contact with the earth's surface and consequently any short-lived radioactive matter in it has had sufficient time to decay, whereas the rain from a thundercloud is falling from air which just a short time before—perhaps less than an hour—was in intimate contact with the earth's surface when the barometer was low and the emanation most likely to escape from the soil.

(*b*) While the air which feeds moisture into a thundercloud over the land comes from the land, the rain-laden air of a hurricane comes from the ocean where the radioactive content of the atmosphere has been observed to be very low.

An interesting aspect of this phenomenon is that the increase of ion formation during a thunderstorm is several fold, a condition not shown by the investigations of the residue from evaporated rain referred to previously. This invites speculation as to its significance when considered in relation to the general study of atmospheric electricity. If the increase of ion formation during a thunderstorm is a quite general phenomenon over the land, a greater air-earth electric current should occur during a thunderstorm for the same potential gradient, thus lending weight to C. T. R. Wilson's theory[2] that the earth's electric charge is replenished by compensating currents flowing beneath thunderclouds, and consequently to a further suggestion as to the cause of the universal-time component of the diurnal variation of the earth's electrical potential gradient in accordance with Whipple's[3] extension of this theory.

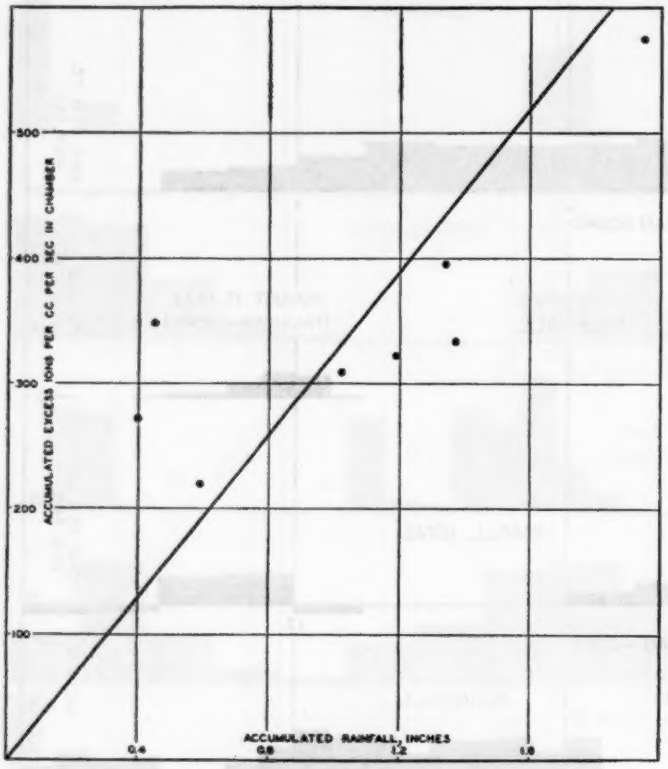

FIGURE 4.—Excess of ionization produced by thunderstorms.

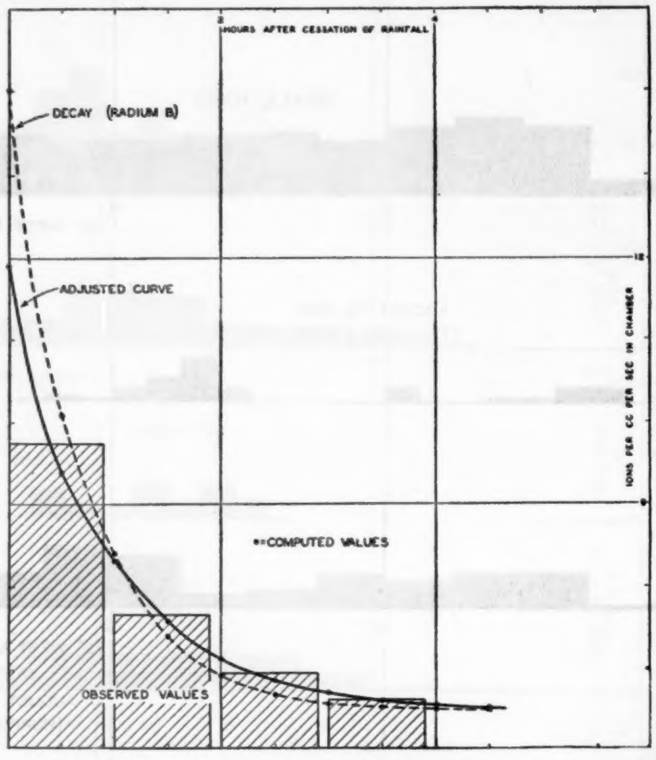

FIGURE 5.—Ionization decay following thundershower (mean 8 showers, Washington, D.C., summer 1933).

[1] V. F. Hess, The Electrical Conductivity of the Atmosphere and Its Gases, pp. 113-14, 1928.

[2] R. Glazebrook, A Dictionary of Applied Physics, 3, 100 (1923).

[3] Q. J. R. Met. Soc., 58, 301-302 (1932).

METHODS AND RESULTS OF DEFINITE RAIN MEASUREMENTS

III. DANZIG REPORT (1)

By Prof. Dr. H. KOSCHMIEDER

[Danzig, Germany]

As is well known, Jevons showed in 1861 that the rain gage produces a disturbance of the air currents, and thereby a disturbance in the distribution of precipitation of such a kind that a part of the rain is carried past the gage, and that the amount of variation from the true rainfall increases with increasing wind velocity. The disturbance which is caused by the instrument itself we shall call the "instrument disturbance" or the "Jevons effect." To correct this, many devices have been invented, of which the best known are the Nipher "funnel shield" and the Wild "fence." As a criterion for the usefulness of such a shelter arrangement the rain gage which under the same conditions gave the greatest quantity, and that quantity, were considered the most accurate. However, Bastamoff and Witkiewitsch (2) showed in 1926 that the amount of rain is not a useful criterion since under certain conditions the influence of the shelter can even give too great amounts of rain, that is, larger amounts than a part of the earth's surface sufficiently removed from all disturbances would receive.

Without knowledge of this important Russian investigation I undertook to construct (3) a rain gage which through its aerodynamic form "a priori" proves that the air movement in its surrroundings remains definite, that is, that the air movement parallel to the earth's surface is not noticeably disturbed by the rain gage.

The sunken rain gage (4).—The task was solved in a simple way by sinking the whole rain gage in the ground in such a manner that the receiving surface is level with the earth. This arrangement offers three advantages.

1. The influence of the form of the rain gage on the air currents disappears completely.
2. The influence of the necessary catchment surface on the air currents in its vicinity is reduced to a minimum through the fact that this surface lies in the layer of least air movement.
3. The influence of the turbulent vertical movements is likewise reduced to a minimum, since these disappear at the earth's surface. Therefore, there is no longer any reason evident that a disturbance of the air currents and a disturbance of the distribution of precipitation should appear with the sunken gage.

On the other hand, the sinking of the catchment area in the earth's surface brings in itself the danger that the drops falling on the ground near the gage will splash and in part fall into the sunken rain gage in the form of spray, and thus falsely indicate too great an amount of rain.

This is the only fundamental objection which can be raised against the sunken rain gage. However, methods can be mentioned which eliminate the spray, and it can be proven whether these methods suffice. After adopting the principle of the sunken rain gage the chief task of the investigation was to test the question of spray. In that the method in itself is capable of proof my investigations go beyond the former ones.

The proof whether the shelter is sufficient against spray or not now follows in a very simple way, through comparing two similar rain gages whose shelter arrangements have different sizes.

If the shelter arrangement is insufficient, then the rain gage provided with the smaller shelter must, as a result of the spray, give a greater rainfall than the one with the larger shelter arrangement. If, on the other hand, the measured amount of rain in the case of both gages is equal, the shelter is sufficient.

The screen in my experiments consisted either of a circular brush whose bristles are turned up and which hold the incident rain drops, the ***brush rain gage*** (5) or a honeycomb shaped, iron grate 5 centimeters thick made of thin sheet iron with 4 by 4 cm openings which permit the rain drops to fall through, but which act on horizontal air currents almost like a continuous surface, ***the honeycomb rain gage*** (6).

The structure of the brush rain-gage is shown in figure 1. Figure 2 shows it on the peak of the Schneekoppe, and, rising beside it an unsheltered Hellmann-Fuess gage for comparative measurements. The grate of the honeycomb rain gage is shown in figure 3. It is sunk in the same way as the brush of figure 1. Different sizes of each kind of sunken rain gage were compared two at a time. In order, however, to determine the quantity of the Jevon's effect and to compare the different types of

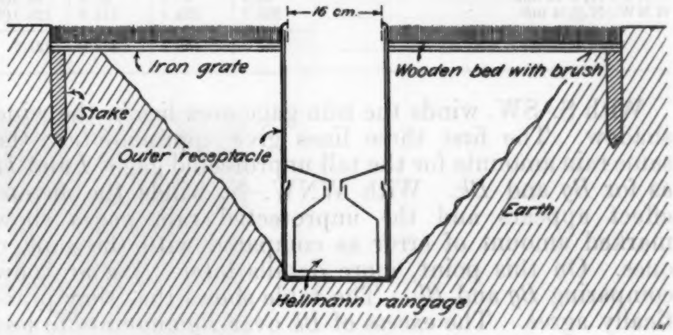

FIGURE 1.—The structure of the sunken rain gage.

rain gage with respect to the uncertainty of single measurements, two normal, unprotected, Hellmann-Fuess rain gages as well as the observatory gage were used. The following are abbreviations for the gages:

Bg=Big brush rain gage, brush diameter 150 cm
Bk=Small brush rain gage, brush diameter 100 cm
Wg=Big honeycomb rain gage, comb diameter 150 cm
Wk=Small honeycomb rain gage, comb diameter 100 cm
} sunken.
I and *II*=Hellmann-Fuess rain gage, catchment area 110 cm high.
St.=Station rain gage, 150 cm high
R=Registering rain gage, 150 cm high
} with Wild "fence" 130 cm high.

Each of the rain gages consisted of three parts, and each had a catchment area of 200 square centimeters except that *St.* had one of 500 square centimeters. The rain gages were tested on the Scheneekoppe in the Riesengebirge. The Scheneekoppe was chosen because at that place there frequently occur heavy rains, often accompanied by high wind velocities. The rain gages stood on the northwest side of the peak and with SE.–WSW. winds lay in the wind shadow of the mountain, or in an extremely turbulent wind movement. A fairly orderly air current over the field of the rain gages is present only with WNW.–N. winds. Therefore only these wind directions are to be used for the determination of the Jevons effect.

II. *The Spray Water.*—The proof that no spray falls into the sunken rain gage is equality of the amounts of

rain which are measured by the upright and the sunken gages so soon as calm or light winds prevail, and the Jevons effect is not noticeable. This condition is completely fulfilled by the brush rain gages, since the 16 cases of rain with low wind velocities give:

$$Bg=141.1,\ I=138.8,\ St.=142.0 \text{ mm}$$

The differences are entirely unimportant, also *Bk* agrees well with *Bg*. The years 1931–32, in which *Bk* lay beside *Bg*, gave $Bg=39.6$, and $Bk=38.7$. Also the excessive rains gave agreement in amount so long as the Jevons effect was not operative. If we take in addition those cases in which the rain gage field lay to the leeward of the mountain, the five excessive rains of the years 1928–32 gave $Bg=166.8$, $I=167.7$, $St.=163.4$ mm.

So soon as the Jevons effect makes its appearance there comes the necessary and sufficient condition for the defective measurement due to spray, in that *Bk* gives no larger rainfall than *Bg*. In the years 1931–32 the rain gages placed near one another gave the following amounts of rain.

Wind (7)	*Bg*	*Bk*	*I*	*II*
	mm	*mm*	*mm*	*mm*
C., 0–3 m/s	39.6	38.7	39.5	38.2
S.–SW., 3–13 m/s	82.0	85.3	90.2	88.1
S.–SW. ≧14 m/s	114.5	118.6	121.9	101.1
WNW.–N, 3–13 m/s	88.0	87.3	67.8	69.2(8)
WNW.–N. ≧14 m/s	233.2	238.4	112.6	125.1(9)
Sum	557.3	568.3	432.0	421.7

With S.–SW. winds the rain gage area lies in the wind shadow. The first three lines give approximately the same rain amounts for the tall unprotected gages *I* and *II* as for *Bg* and *Bk*. With WNW.–N. winds the Jevons effect appears and the unprotected rain gages show marked amount of error as compared with the sunken ones. On this point, more details later. We are now comparing *Bg* and *Bk*. The table shows that they practically agree. The excess of *Bk* over *Bg* amounts to less than 2 percent of the amount measured by *Bg*. The difference is entirely insignificant.

Downpours of rain provide a further check: If spray water were present then in downpours the ratio of *Bg* to *I* must have been greater than in moderate rains. This does not hold true, as is shown by a thoroughgoing investigation of eight downpours with a total fall of 337 mm. Consequently, the large brush represents a complete protection against spray; therefore the brush rain gage can be considered as a normal rain gage.

The honeycomb rain gages in 1931-32 gave smaller values than the brush rain gages. From this it may be thought that the honeycomb gage presents a better protection against spray than the brushes. There is something wrong, for in the first place it has just been proven that the brush represents a complete protection, and in the second place the small honeycomb rain gage gives a smaller quantity of rain than the larger one, namely, $Wk=518.2$ as compared with $Wg=531.8$, while *Wk* must have been greater than *Wg* if spray were present. To what these disagreements are related must still be made clear. Until then, the experiments with the honeycomb gage cannot be regarded as closed. However, the disagreements are small, especially in the cases in which a wind influence appears. In the above-named wind groups the percentage deviation with respect to *Bg* amounted to:

	C.	SW. 1	SW. 2	NW. 1	NW. 2	Average
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Wg	−8.6	−3.9	−4.5	+2.3	−6.8	−4.6
Wk	−15.9	−16.2	−11.5	+3.2	−3.9	−7.0
I	−0.3	+10.0	+6.5	−23.0	−51.7	−22.5
II	−3.5	+7.4	−11.7	−21.4	−46.4	−24.4

Thus with northwest winds the deviations of the comb gages with respect to *Bg* amount to only one tenth of the deviation of the upright rain gage. Moreover, its sign changes, while the sign of the variations of the upright gage remains the same.

I believe that in other lands—for example, on the flat islands of the North Sea—a still better agreement would result between the comb and brush rain gages than on the Schneekoppe, where the air movement is somewhat regular only in the case of northwest winds.

Such a result would be very desirable, since the honeycomb rain gage shows important technical advantages when compared with the brush rain gage. If it is zinc-coated, it is sufficiently independent of the influence of moisture; it is not clogged by transported sand which readily falls through the openings, and it can be walked on without being damaged.

III. The uncertainty of the single measurements could be determined during the series of experiments, since there were available two patterns of each rain gage. A reasonable measure for the average uncertainty of a single measurement of each of the rain-gage types would be given by the expression $\triangle B=\frac{1}{n}\Sigma\left|Bg_i-\frac{Bg_i+Bk_i}{2}\right|$, $\triangle W=\frac{1}{n}\Sigma\left|Wg_i-\frac{Wg_i+Wk_i}{2}\right|$, $\triangle H=\frac{1}{n}\Sigma\left|I_i-\frac{I_i+II_i}{2}\right|$, where n is the number of the occasionally available pairs of values, and $i=1$ ------- n is the index with respect to which the summation is taken. It becomes:

	$\triangle B$	$\triangle W$	$\triangle H$	($\triangle St.$)	
NW. 1	±3.5	±3.5	±5.8%	(±5.6%)	*St.* compared with $\frac{Bg+Bk}{2}$
NW. 11	±6.5	±5.7	±15.2%	(±11.8%)	

Thus the uncertainty of a single measurement with the sunken rain gage amounts to only one half to one third of the uncertainty with the upright gage.

IV. *The instrumental disturbance of the normal unprotected rain gage.*—Since, as has been shown, the sunken brush rain gage can be considered as a normal rain gage, the Jevons effect of the normal upright rain gage can be established quantitatively with it, as a function of the wind velocity. And indeed there is interest in the dependence of the Jevons effect on that velocity of the wind which prevails at the height of the catchment surface of the upright gage; that is, at 110 cm above the ground. Therefore, in 1931–32 the wind velocities at this height above the rain measuring field were observed and for the preceding years they were reduced to this height by the aid of comparative measurements on the tower. (For full details, reference may be made to the original communication.) Here it may merely be mentioned that the wind velocity at the height of 110 cm was two thirds to one half that which was measured on the tower of the observatory, 17.2 m above the ground.

FIGURE 2.—The sunken brush rain gage on the Schneekoppe. (Behind it a normal upright Hellmann-Fuess rain gage.)

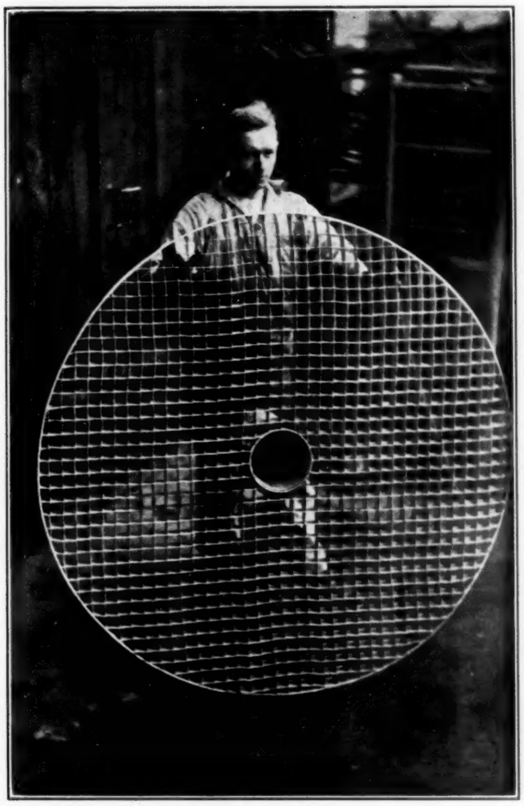

FIGURE 3.—The comb grate of the honeycomb rain gage. In the middle, the outer vessel, in which the usual 3-piece Hellmann-Fuess gage is placed.

The mean deficits were calculated for the different intervals of wind velocity whose main values are evident from figure 4. These are marked in figure 4 by circles. It is seen that up to the velocity of 12 m.p.s. the scatter from the smoothed curve is small, therefore up to this value the curve can be considered accurate. It gives the following smoothed deficits, D, for the upright normal gage and the following reduction factors, f, relative to the wind velocities, v, prevailing at the height of 110 cm:

$v=0$	2	4	6	8	10	12	(14)	16 m/s
$D=0$	4	10	19	29	40	51	(62)	(71) %
$f=1$	1.04	1.11	1.23	1.41	1.67	2.0	(2.6)	(3.4)

At about 9 m.p.s. the results of the upright gage are to be multiplied by 1.5 in order to obtain the true amount of rain; at about 12 m.p.s. by 2, at about 15 m.p.s. by 3.

These figures hold for ordinary rains. In very fine mists, whose intensity does not exceed 0.2 mm per hour, the upright gages give a greater rainfall than the sunken ones, a result, perhaps, of the mechanical depositing of drops. An upright brush rain gage, which was not mentioned above, also gave an excess of rainfall. With it the excess of rainfall relative to $(Bg+Bk)/2$ was 12 percent under NW. 1, and even 44 percent under NW. 2. This shows that even a horizontal surface, or a surface parallel to the ground like the elevated brush, presents an obstacle to the wind, since the wind is never directed horizontally but continually oscillates about the horizontal because of turbulence.

For this reason the sinking of the rain gage in the surface of the ground appears to be the sole possibility of preventing every noticeable effect of the rain gage on the air movement and the distribution of precipitation and of measuring the rain without error. However, the practical importance of the sunken rain gages is decreased in that they are useless for the measurement of snow (and perhaps hail). Nevertheless, it would be unfair to require of *one* instrument the solution of different problems; one must be fairly well satisfied if one question is correctly solved. To me there appeared an unconditioned necessity of producing proof of this, since the similar propositions of Stevenson and Buchan have remained unfruitful because they lack reference to definite proof.—*Translated by R. J. Martin.*

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(3) H. Koschmieder, Methods and results of definite rain measurements.

III. Hydrolog. Conference of the Baltic States, Warsaw, 1930.

IV. Hydrolog. Conference of the Baltic States, Leningrad, 1933.

(4) A sunken rain gage has been in use for nearly 20 years at the Sloutzk Meteorological Observatory at Leningrad (Director Sawinoff). However, this gage is not protected against spray.

(5) Almost 100 years ago the Englishman Th. Stevenson suggested a similar rain gage (Dinglers Polytechnical Journal, 86, p. 28, 1842). This suggestion had been completely forgotten. Neither in the experiment of Jevons, 1861, nor in the textbook literature is it mentioned. I myself received knowledge of Stevenson's suggestion only through the Patent Office. Stevenson suffered the same fate with his suggestion as Welsh with the aspiration thermometer; chiefly, perhaps, because he did not carry out experiments with his rain gage.

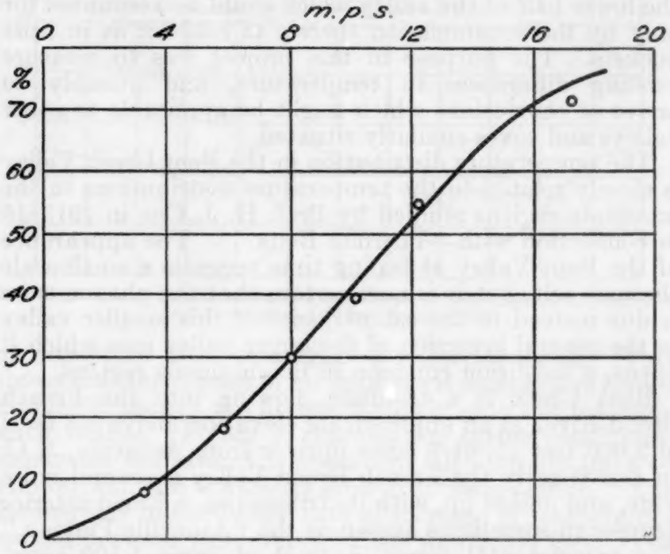


FIGURE 4.—The amount of error of the normal upright rain gage (Jevons effect) in percent of the true amount of rain as a function of the wind velocity at the elevation of the catchment surface (110 cm).

(6) The honeycomb rain gage is very similar to the pit gage of A. Buchan, which makes use of a network as compensation for the earth's surface. This compensation is certainly not as adequately sufficient as the honeycomb grate I used; also the net has a technical disadvantage in that the exchange of the rain gage is not very simple. On the other hand, the honeycomb grate can be stepped on so that placing and removing the gage offers no difficulty. Compare in this respect also the experiments of C. D. Stewart (Quar. J., R. Met. Soc., 62, 1926) which refers to a suggestion of E. Gold (Met. Mag., 57, 1922). Both works were not accessible to me in the original.

(7) Wind velocities and directions from the registers on the 17-meter high tower of the Schneekoppe Observatory.

(8) Uncorrected 74.2 mm.

(9) Uncorrected 145.1 mm.

TEMPERATURE VARIATIONS ALONG A FORESTED SLOPE IN THE BENT CREEK EXPERIMENTAL FOREST, N.C.

By LELAND T. PIERCE

[Weather Bureau Office, Asheville, N.C., January 1934]

Beginning with October 1932, a project has been operated in the Bent Creek Experimental Forest, near Asheville, N.C., of the Appalachian Forest Experiment Station to determine the temperature characteristics responsible for a noticeable differential between the leafing times of trees at different levels in the Bent Creek Valley. A retardation of as much as 2 weeks has been observed in the lower half of the valley which could be accounted for only by the accumulation therein of cold air as in frost pockets. The purpose of this project was to measure existing differences in temperature, and possibly to arrive at conclusions which might be applicable to other valleys and coves similarly situated.

The temperature distribution in the Bent Creek Valley is closely related to the temperature distributions in the mountain regions studied by Prof. H. J. Cox in 1913–16 in connection with "Thermal Belts." [1] The appearance of the Bent Valley at leafing time suggests a small-scale thermal belt, but it is now certain that the phenomenon is due instead to the submergence of this smaller valley in the general inversion of the larger valley into which it opens, a condition common in mountainous regions.

Bent Creek is a tributary flowing into the French Broad River at an approximate elevation above sea level of 2,000 feet about 7 miles upriver from Asheville, N.C. In this vicinity the French Broad Valley is several miles wide, and makes up, with its tributaries, a broad interior depression sometimes known as the "Asheville Plateau." The experimental forest, a tract of some 1,100 acres, lies within the Bent Creek Valley which has a NNE.–SSW. axis and opens toward the north. The valley is almost completely forested with mixed hardwoods, there being only two small cleared areas, one at the mouth, the other extending on the eastern side over the top of Glenn Bald. For the most part, the slopes on either side are very irregular, facing in various directions, but one long, continuous slope leads northwestward down from Glen Bald at 2,692 feet elevation to the creek bottom at 2,100 feet. Along this slope the weather stations were installed late in September 1932.

Three stations were established. The base station was placed at 2,100 feet above sea level, near the creek bottom; the other two at elevation intervals of 200 feet were located at 2,300 and 2,500 feet, respectively. These were all on a regular slope and under a forest cover which has as nearly a uniform crown density as is ordinarily possible to find. Each was equipped with maximum and minimum thermometers, Weather Bureau type hygrothermograph and soil thermometers. The hygrothermographs were checked weekly with a sling psychrometer and it is believed that to an acceptable degree of accuracy these three stations recorded temperatures and humidities accounted for purely by differences in elevation and position in the valley. Credit for this work belongs to Mr. E. M. Manchester, resident manager at the experimental forest, who tended the station equipment.

In the measurement of inversion temperatures in a valley it is customary to place the weather stations in the open. However, these stations were placed under forest cover and therefore the results undoubtedly are somewhat different from those which would have been obtained in the open. In particular the unexpected frequency of large inversions here found may be accounted for in part by the fact that the stations were placed under forest cover since trees interfere with atmospheric circulation and thereby favor stratification of the air, a condition essential to inversion.

THERMAL CONDITIONS IN A MOUNTAINOUS REGION

To understand more thoroughly the reasons for the results obtained, it is well to explain briefly the thermal characteristics of a mountainous region. There temperatures vary greatly from place to place and from elevation to elevation principally on account of air drainage.

The surface of the earth continuously loses heat by radiation, and therefore on still clear nights ground surfaces become cool and in turn correspondingly chill the adjacent air. This cold air drains down the mountain sides, flowing water-like into the valleys below where it is further cooled by radiation. Thus the valleys become filled with "lakes" or "rivers" of dense, cold air tending always to drain out wherever possible into regions of lower elevation. The more gentle the slope the more sluggish the drainage, and vice versa. In this section most valleys have gentle slopes and on still, clear nights so fill with cold air as completely to submerge therein the tributary coves and glens. As this drainage process continues during the night, the level of maximum temperature, marking the top of the inversion layer, creeps gradually up the sides of the valleys, and finally reaches its greatest height at the time of the minimum temperature. This usually occurs when the rising sun puts an end to the net heat loss. The maximum height attained by the upper limit of the inversion layer, because it is reached at the time of lowest temperature, marks the elevation of the thermal belt in that particular valley.

In this section where the popular mind has been focused upon that phenomenon by Professor Cox's work, there is a good deal of misconception regarding the nature, and especially the level, of the thermal belt. Casual thought in the light of processes involved leads to the conclusion that there must be a definite range of elevation in a mountainous region within which the thermal belt will always be found. However, such is not the case. Rather than occurring at a definite elevation above sea level, the belt of highest minima is to be found at a specific height above the floor of each individual valley which displays the phenomenon at all. Indeed, not every valley has a thermal belt since topographic conditions must be favorable for the development of this condition. During a night of free radiation the valley fills up with cold air, presumably at a more or less definite rate, reaching its greatest depth at the time of the minimum temperature. In individual cases the height which will be reached by sunrise depends upon the length of the night, rate of radiation, cloudiness, and wind velocity as well as upon the local topographic conditions which allow for or prevent a normal filling up of the depression.

In a mountainous region such as the Southern Appalachians, the majority of valleys and coves cannot boast a thermal belt, simply because they are not deep enough. Each may have its own inversion, but the depth of the inversion layers as governed by topography, is so great that the valley is completely filled by drainage from higher land. In this case the level of the highest minima

[1] Cox, Henry J. Thermal belts and fruit growing in North Carolina. MO. WEA. REV. SUPPLEMENT No. 19. Washington, 1923.

will be at, or well above, the ridge on either side. This is the state of affairs in the Bent Creek Valley, a tributary with higher mountains on all sides. The places of minor inversions, such as tributary valleys, submerged in the main valley inversion, often are called frost pockets. It might be better, however, to call these frost coves and restrict the name "pocket" to a place of little or no outlet.

In this connection it should be mentioned that the depth of the inversion layer is not the same on every inversion night. A reduction in the length of time during which free radiation goes on, as occasioned by cloudiness part of the night, or by a reduction in the normal rate of heat loss due to the presence of a smoke or haze layer, or partial cloudiness, will prevent its reaching the normal maximum depth. Many cases of this have been recorded at Bent Creek. Table 2 indicates the frequency of this condition as the number of nights on which the temperature was highest at the 2,300-foot level. In these cases it may be assumed that the belt of highest minimum is higher or lower than this level when the minimum is found at the elevation of 2,100 or 2,500 feet of the bottom or top, respectively.

An inversion of temperature is the rule in a mountainous section like this, occurring much more frequently than the reverse, which is normal for the free air. Nights of "norm" conditions are so much in the minority that aver-

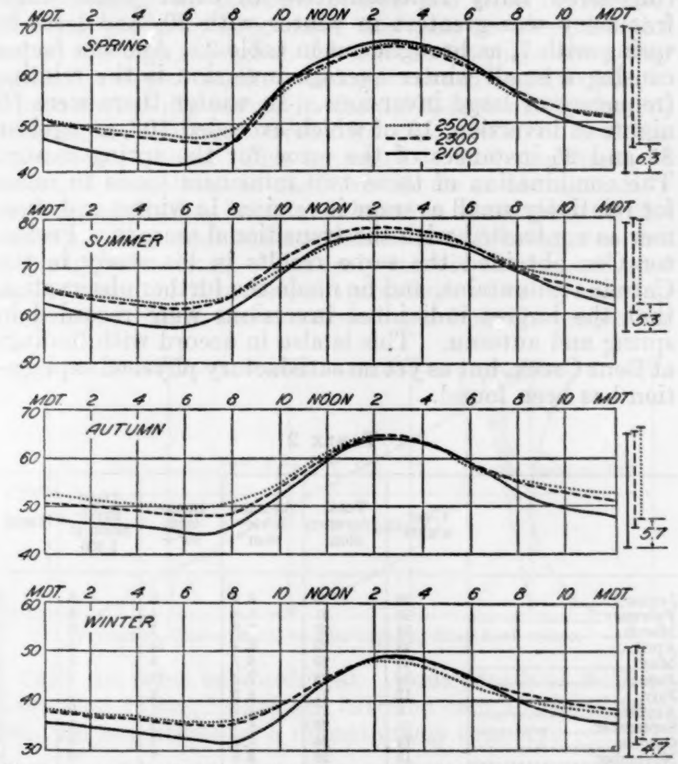


FIGURE 1.—Average diurnal march in temperature each season for the three stations.

age temperatures for a month or longer period invariably indicate a substantial inversion. Diurnal curves of mean seasonal temperatures in figure 1 bring out this fact.

AVERAGE SEASONAL TEMPERATURE CONDITIONS

Figure 1 shows graphically the diurnal variations in seasonal average temperatures for the three elevations. As is to be expected, the diurnal curves for all seasons are very similar, though the greatest variations are seen in the transitional seasons. Temperatures are lowest, for the most part, at the 2,100-foot level. This condition extends throughout the entire 24 hours, with the exception of mid-afternoon, during the period January to May, inclusive. This probably is due to the northwestern exposure, the bottom station being slightly more sheltered than those higher up. The highest maxima during the remainder of the year occurred about as frequently at the 2,300-foot as at the 2,500-foot elevation.

The 2,100-foot curve is most widely separated from the other two during the early morning hours but the increase

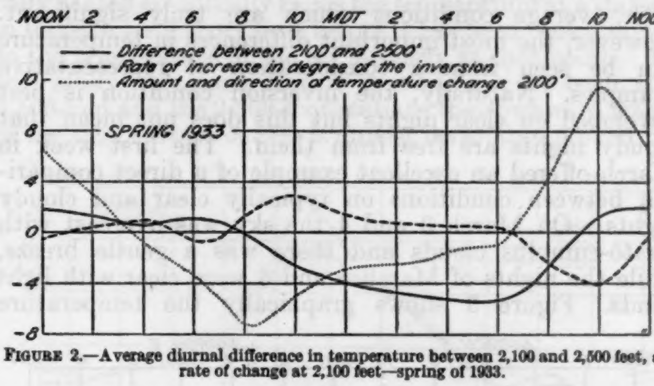


FIGURE 2.—Average diurnal difference in temperature between 2,100 and 2,500 feet, and rate of change at 2,100 feet—spring of 1933.

in departure after midnight is relatively small. This shows that the process of air drainage is most active before midnight, though the inversion slowly grows in intensity until sunrise. Figure 2, representing spring conditions, illustrates the rate of temperature fall at the 2,100-foot station, and also the steady growth of the inversion. The broken line indicates the rate of increase in temperature spread between the levels of 2,100 and 2,500 feet. The greatest 2-hourly changes appear between 8 p.m. and 10 p.m., the increase gradually tapering off from then until sunrise when the trend is reversed.

The ranges in temperature at all stations are greatest in spring and least in summer as might be expected from the transitional nature of the spring season and the rather settled conditions in summer. Also, the greatest inversions were recorded in spring and fall. This agrees with the findings of Professor Cox, but it is difficult to assign a specific reason for it other than that in these seasons there are fewer nights of norm conditions.

Table 1 brings out the feature of highest maxima temperatures at the bottom station during the 5-month period beginning with January, mentioned above. This situation presumably is owing largely to the absence of foliage on the overhanging trees during the winter and spring months which allows the sunshine to reach the surface in largest amount. The lowest minima, of course, always were recorded at the lowest station. The average temperature difference between this and the 2,500-foot level was least in winter and greatest in spring for reasons to be presented later.

Considering the average temperature level, as influenced partially by variations in the extremes, it can be said that the coldest part of the Bent Creek Valley is the bottom, and the warmest is at the higher elevations. The average annual temperature for the 2,500-foot level was 56.2° and at the 2,300-foot level, 55.7°, while at 2,100 feet it was only 53.7°, or 2.5° lower than at 2,500 feet. Assuming the thermal belt to be at or above 3,000 feet, as Professor Cox found, and as appears to be true from the success with orchards at these higher elevations, there is probably as much as 3.5° or 4° difference between the average temperature at the valley bottom and at Manning

Top, the head of this valley, which rises to 3,057 feet. It is conceivable that the growth of vegetation would for this reason be most rapid in the higher portions of the valley. Indeed, observation bears this out though the most noticeable differential is caused by the later occurrence of freezing temperatures in lower portions of the valley.

EFFECT OF CLOUDINESS ON INVERSIONS

The foregoing discussions have dealt almost entirely with average conditions which are truly significant. However, the most important differences in temperature can be seen from a consideration of representative examples. Naturally, the inversion condition is best developed on clear nights but this does not mean that cloudy nights are free from them. The first week in March offered an excellent example of a direct comparison between conditions on typically clear and cloudy nights. On March 3 and 4 the sky was overcast with strato-cumulus clouds and there was a gentle breeze, while the nights of March 5 and 6 were clear with light winds. Figure 3 shows graphically the temperature

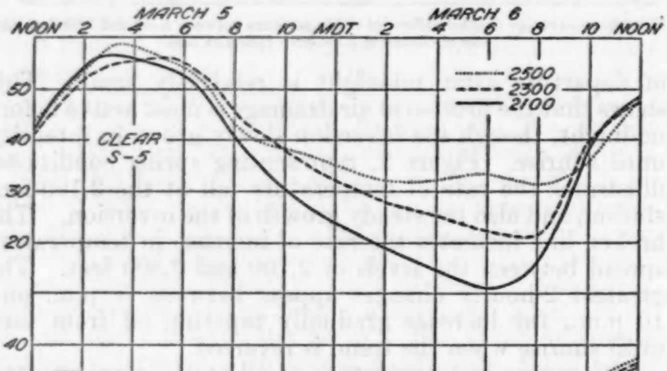


FIGURE 3.—Temperature march on characteristic clear and cloudy nights. (March 3–4, 1933, cloudy; March 5–6, 1933, clear.)

march from noon to noon covering those 2 nights. On the clear night there was an inversion amounting at 6 a.m. to 22°, this being the greatest for the entire year. The greatest difference between the two outside levels on the cloudy night was 1°. These instances represent the extreme condition, but they show the tendency for cloudiness and wind to prevent inversions.

TABLE 1.—*Average monthly maximum, minimum, and mean temperatures*

Elevation (feet)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Maxima:													
2,500	53.7	47.6	57.9	67.8	78.0	81.3	79.3	77.3	*78.4*	*65.7*	*53.5*	50.4	----
2,300	54.1	48.1	57.2	67.5	78.6	*81.5*	*80.9*	*77.4*	78.3	65.0	53.1	*51.0*	----
2,100	*54.6*	*48.8*	*58.1*	*68.7*	*79.6*	79.8	78.2	76.3	77.3	65.5	52.4	50.5	----
Minima:													
2,500	35.2	27.4	35.3	43.5	55.8	60.4	61.7	63.2	61.8	46.8	33.2	34.4	----
2,300	34.0	27.6	34.7	43.0	54.7	58.8	60.9	61.2	59.4	44.8	32.6	34.0	----
2,100	*29.2*	*24.2*	*29.6*	*35.8*	*50.5*	*52.4*	*58.0*	*59.2*	*56.0*	*40.8*	*28.1*	*30.5*	----
Means:													
2,500	*44.4*	37.5	*46.6*	*55.6*	*66.9*	*70.8*	70.5	*70.2*	*70.1*	*56.2*	*43.4*	42.4	56.2
2,300	44.0	*37.8*	46.0	55.2	66.6	70.2	*70.6*	69.3	68.8	54.9	42.8	*42.5*	55.7
2,100	41.9	36.5	43.5	55.2	65.0	66.1	68.1	67.8	66.6	53.2	40.2	40.5	53.7

Italic figures indicate maxima and mean highest.
Italic figures indicate minima lowest.

Twelve selected clear and cloudy nights in spring and summer were studied for the purpose of determining the average effect of cloudiness upon temperature inversions. In order to isolate the cloudiness factor care was exercised to choose nights having approximately the same wind, and to avoid nights with rainfall. A direct comparison was made on the basis of degree of inversion and significant results were obtained. On the clear nights the average maximum inversion recorded at 6 a.m. was 14°, and on the cloudy nights, 5.2°, or less than half that on clear nights. Radiation goes on at all times, clear or cloudy, but a cloud blanket ratains large amounts of heat which otherwise would have been lost to space. Another characteristic effect of cloudiness is that it slows down the rate of development of the inversion. On the clear nights the maximum inversion of 14° was only 1.3° greater than that at midnight. On the cloudy nights the 5.2° inversion at 6 a.m. was 1.7° greater than the midnight value, despite the fact that the total inversion was considerably smaller.

Mention has been made of the fact that, when considering average seasonal temperature marches in night temperatures, a marked inversion is shown. The degree of average inversion will be increased with an increasing frequency of clear nights and decreased by the inclusion of more nights of norm conditions. It is probable that the seasonal variations in the degree of average inversion, then, is largely a function of the frequency of norm conditions. In the year of this study, 1932–33, which may be considered fairly representative of other years, their frequency was greatest in winter with 20, and least in spring with 7, as brought out in table 2. Another factor causing a small winter average inversion is the relative frequency of large inversions. In winter there were 70 nights of inversion, 19 of which exceeded 10°, as against 85 and 25 instances of the same for the spring season. The combination of these two influences tends to make for relatively small average inversions in winter and summer as contrasted with the transitional seasons. Professor Cox obtained the same results in his study in the Carolina mountains, and he made the further observation that the largest individual inversions were recorded in spring and autumn. This is also in accord with findings at Bent Creek, but as yet no satisfactory physical explanation has been found.

TABLE 2

	Clear nights	Total inversion	Average inversion	Inversion, 10°+	Days maximum at 2,300	Norms
January	10	25	8.2	8	6	5
February	10	21	5.8	4	6	7
March	14	27	7.3	7	9	4
April	13	29	8.4	14	5	1
May	15	29	6.1	4	6	2
June	19	28	7.2	11	2	2
July	12	27	4.5	3	2	4
August	9	27	4.7	1	0	3
September	12	23	8.1	7	1	6
October	14	25	7.7	7	3	3
November	15	26	6.5	7	10	3
December	6	24	6.9	7	12	8
Spring	42	85	7.3	25	20	7
Summer	40	82	5.5	15	4	9
Autumn	41	74	7.4	21	14	12
Winter	26	70	7.0	19	24	20

CHARACTERISTICS OF DIURNAL TEMPERATURE VARIATIONS

Each distinct weather type has its own characteristic form of vertical temperature distribution in a valley such as Bent Creek. Figure 4 presents these different types. Three nights were selected from the April records, 1 of which the sky was clear, 1 cloudy, and 1 on which rain

fell for the greater part of the night. There was a typical large inversion on the clear night, a smaller, shallower one on the cloudy night, and the rainy night was characterized by approximately norm conditions. The gradient on the cloudy night suggests the presence of a distinct thermal belt between the 2,300- and the 2,500-foot levels since there is an inversion below the lower of these and no further increase at the upper. It is probable that with the slower rate of heat loss by radiation, the depth of the inversion layer did not become great enough to fill the valley completely. A condition of this nature is relatively infrequent, as seen in table 2, though it occurred 10 times in November and 12 in December. These two were unusually cloudy months, and indeed this form of temperature distribution is invariably associated with night cloudiness. It represents a partially developed inversion.

The characteristics of the three station sites are well brought out by comparing the rates of temperature change throughout the 24-hour period. These values are given in figure 5 for the spring season. The three stations, situated as they are on a uniform northwest slope, receive sunshine in the morning at almost the same time, and therefore show simultaneous recovery from the minimum. However, the rate of rise is much greater at the 2,100-foot station than it is higher up the slope. This, of course, is due to the rapid dissipation of the inversion. Sixteen selected inversion mornings showed a lag in time of recovery averaging 45 minutes behind the time of sunrise. This lag probably represents the time required for the sun to rise high enough in the heavens to shine down this particular slope. In the evening, between 6 and 8 o'clock, a pronounced dip occurs in the 2,100-foot station curve, bringing it well below those for the 2,300-foot and the 2,500-foot stations. This indicates an early beginning of inversion conditions at the lower levels as occasioned by the bottom station being enveloped in the shadow of the western valley wall while sunshine is still being received at the upper stations. This early start in the formation of the inversion is, of course, characteristic of valleys having a north-south axis, and must be absent from those opening

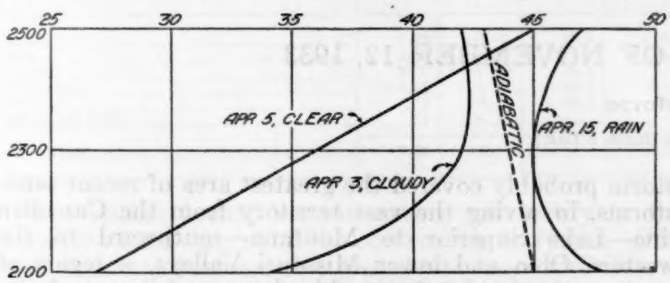


FIGURE 4.—Characteristic weather types on three April nights.

toward the west or southwest. Considerations such as these tend to emphasize the extreme complexity of temperature conditions in a mountainous country.

TOTAL RADIATIONAL COOLING

In arriving at the actual amount of radiational cooling which takes place by virtue of valley conditions, one cannot depend entirely upon the recorded temperature differences. Cold air draining down the mountain side undergoes dynamical heating with its descent at the rate of approximately 1° for each 200 feet drop. Allowing, then, for a 2° heating of air which flowed down from the 2,500-foot to the 2,100-foot level, the total radiational cooling at the valley bottom is 2° greater than the actual difference recorded. For instance, on March 6, when the actual temperature difference was 22°, the total cooling was 24°. Considered from this standpoint, the average seasonal cooling due to radiation becomes 9.3° for spring, 7.5° for summer, 9.4° for autumn, and 9° for winter months.

Professor Cox advanced the idea that air drainage does not proceed down the slope continuously, but rather in spurts. This was based upon the observed irregularity of downward night-temperature curves at slope stations. As a mass of cold air flows down the slope, the dynamically heated air actually raises the temperature at a station in its path for a short time before it has been cooled down to the temperature of the air formerly at that point. In this study the same feature is evident. At both the 2,500-foot and the 2,300-foot stations the downward trend of the temperature curves is almost invariably broken by

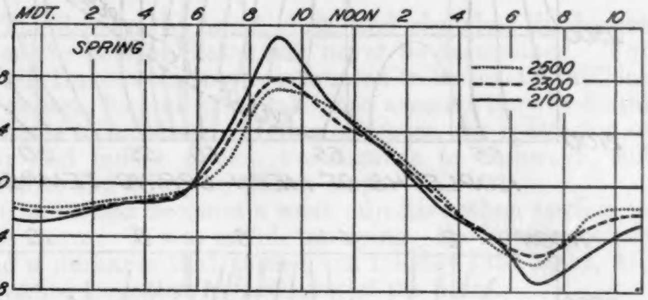


FIGURE 5.—Amount and direction of 2-hourly temperature changes, spring of 1933.

momentary rises, while this feature is not in the least apparent at the bottom station where the air has stagnated.

ISOPLETH CHARTS

One of the most convenient and readily understandable methods of representing graphically the temperature changes taking place throughout the day at different elevations is by use of the isopleth chart. By this means the rate of temperature change, the direction of the gradient at any particular time and the amount of difference between different levels can quickly be observed. Such charts have been prepared for average conditions, and also for the 10 nights of greatest inversion in each season. The spring set is presented as a means for making clearer the changes which took place in this valley. The rapid development of the inversion is clearly shown by the horizontal density of the lines, and the steepness of the vertical temperature gradient is shown by their vertical density. The average sunrise and sunset times are indicated by the heavy double lines. It is probable that the growth of the inversion is a continuous process, the level of maximum temperature being gradually lifted as the valley fills with cold air. The dotted lines represent the progress of this process. The quickness with which this warm layer reaches the top station is in itself a good indication that the height of the thermal belt is considerably above the 2,500-foot elevation, and that this phenomenon does not take place within the confines of the valley. The rapid dissipation of the inversion after sunrise is especially noticeable.

It is evident from the data collected in this study that the lower portion of the Bent Creek Valley, in which the leafing of trees is materially retarded, constitutes a sort of frost pocket within a much larger basin, and which, because of its relatively small size, has no true thermal belt of its own, such as occurs along the walls of the including, greater valley at an elevation of approximately 3,000 feet above sea level.

Obviously the conditions in Bent Creek Valley are common to all like valleys and coves in the mountainous region whose floors have a gentle slope, and are dominated by a larger valley system. Coves on steeply sloping mountain sides are not frost pockets since cold air drains out as fast as it accumulates. The direction in which the valley extends undoubtedly has a direct bearing upon the diurnal changes; inversions probably develop more quickly in those having a north-south axis than in those opening toward the western sun. Variations in the extent of inversions in mountain valleys and coves, and in the rates of their formation and dispersal are well-nigh infinite.

This study is far from exhaustive, even for this particular valley, but it serves to throw light upon the changes in temperature which take place in similar valleys. If stations had been located in different portions of this valley they undoubtedly would have yielded slightly different results, but it is certain that those differences would have been quantitative rather than qualitative.

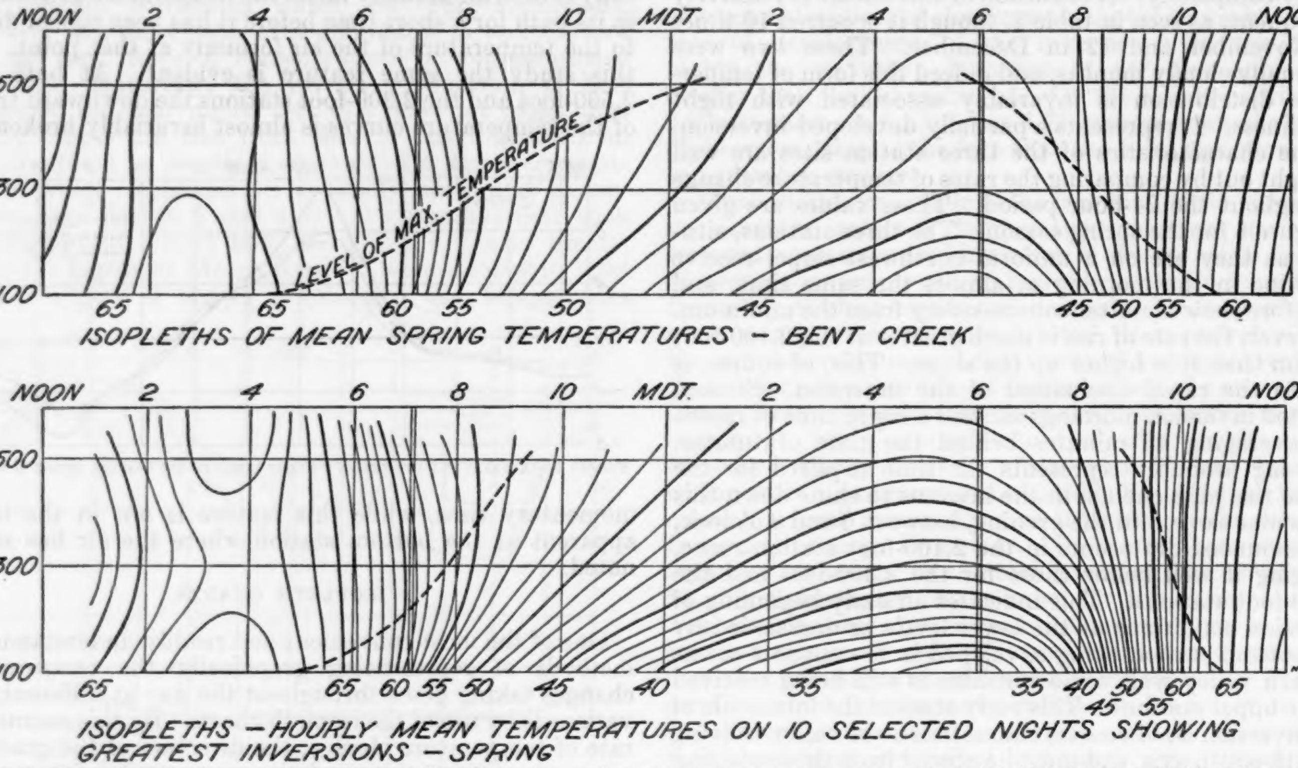


FIGURE 6.—Upper: Isopleths of mean spring temperatures, Bent Creek. Lower: Isopleths, hourly mean temperatures on 10 selected nights showing greatest inversions—spring.

THE GREAT DUSTSTORM OF NOVEMBER 12, 1933

By M. R. HOVDE

[Weather Bureau Office, Huron, S.Dak.]

In the climatological reports of the Great Plains will be found many accounts of severe dust and sandstorms. The MONTHLY WEATHER REVIEW has published narratives and articles concerning the outstanding storms of this nature. The duration and severity of duststorms depend on (1) the type of storm; (2) the covering of the soil, whether bare or vegetated; (3) the rainfall preceding the storm, or water content of the surface.

The whirlwind type (thunderstorms, tornadoes, and whirlwinds) may cause duststorms over limited areas only and their duration is short, in keeping with the characteristics of these local disturbances.

In the shift-wind type one refers to the area of low pressure with a characteristic trough and wind-shift line. In nature's effort to restore equilibrium, winds of gale force may raise dust along the wind-shift line.

The third type may be called the straight-wind type. Such a type calls for an area of high pressure and steep barometric gradient, which occurs only near the forward border of such area.

In the great duststorm of Sunday, November 12, 1933, the third or straight-wind type prevailed. This duststorm probably covered the greatest area of recent sandstorms, involving the vast territory from the Canadian line—Lake Superior to Montana—southward to the western Ohio and lower Missouri Valleys, a region of greater extent than the combined areas of France, Italy, and Hungary. Over South Dakota the dirtstorm was the severest within the memory of old settlers and cooperative observers. In adjoining States the prevalence of dust varied according to surface protection by vegetation or recent precipitation. The northern portions of Minnesota and North Dakota had a light snow layer and during the storm received precipitation which reduced the dust annoyance to a great extent. In Iowa the high winds blew much corn from the stalks, visibility was low and artificial lights were required during the day. Flying schedules on the airways into the Dakotas and Manitoba, Canada, were canceled.

The morning map of the 11th revealed a disturbance moving rapidly southeastward over Alberta, Fairview, 29.60 inches, and the anticyclone was centered at Boise, Idaho, 30.54 inches. On the morning of the 12th the Alberta storm reached southern Manitoba, Canada,

Pembina, N.Dak., 29.24 inches, while the anticyclone remained stationary and maintained a somewhat greater intensity over Idaho and Washington, Spokane, Wash., 30.60 inches.

This gradient was sufficient to cause winds of gale force over the northern and central Great Plains. Owing to severe drought all crops, including pasture grass and hay, had failed over vast areas in South Dakota, a condition that served to accentuate the dense clouds of dirt and dust. In table 1 wind velocities are given for widely scattered stations.

TABLE 1.—*Maxima wind velocities for periods during the day (m.p.h. and C.S.T.)*

Station	7 to 10 a.m.	10 a.m. to 1 p.m.	1 to 4 p.m.	4 to 7 p.m.	Extreme velocity
Williston, N.Dak	46	38	21	11	53
Bismarck, N.Dak	50	46	35	25	56
Devils Lake, N.Dak	40	35	34	29	41
Fargo Airport, N.Dak	50	46	45	45	----------
Duluth, Minn	21	22	38	41	44
Pembina, N.Dak	47	47	37	30	----------
Rapid City, S.Dak	41	37	35	30	44
Huron, S.Dak	45	44	37	27	51
Alexandria, Minn	34	42	48	35	----------
Minneapolis, Minn	34	38	41	36	46
Valentine, Nebr	31	35	37	34	48
Sioux City, Iowa	32	43	46	43	51
Davenport, Iowa	30	34	40	[1] 43	[2] 56
Kansas City, Mo	21	24	27	35	40

[1] 7:29 p.m. [2] 7:31 p.m.

The picture of the awe-inspiring storm becomes more impressive when the following facts of soil moisture and surface water content are visualized. The less than 8 inches of rain in the 5 months preceding the storm (see table 2), coupled with the fact that June was the hottest of record and July a near record breaker for heat, necessitated that drought and extreme dryness be prevalent.

TABLE 2.—*Average precipitation and temperature for South Dakota, 1933 (95 stations)*

Month	Precipitation	Departure	Temperature	Departure
June	1.48	−2.07	76.5	+10.0
July	2.34	−.29	77.5	+5.0
August	2.35	+.02	70.3	−.1
September	1.21	−.48	66.7	+5.2
October	.12	−1.19	49.3	+.9
November 1–12	.13	−.16	----------	----------
Total	7.63	−4.17	----------	----------

The visibility data are interesting and testify to the severity of the storm and the obstruction to vision. The reports reveal a remarkable precedent of zero visibility at distant points caused only by a dust-laden atmosphere. In table 3, the visibility is given for selected hours throughout the daytime from widely scattered stations. With the eastward drift of the storm, it naturally followed that low visibility was reached late in the day at the more eastern stations.

The usual manifestations of atmospheric electricity are lightning, the aurora, and St. Elmo's fire, but on this date there were other evidences of a charged atmosphere. Farmers received shocks when closing the standard pasture gate (barbed wire and small posts); telephone poles (not power lines) were burned and charred; power lines were troubled; automobiles stalled; and radio aerials crackled.

Houses, well built with tight windows, weather-stripped and with storm sash, could not keep out the unwelcome entrance of fine, powderlike dust. Every home and building had to be cleaned from basement to roof.

TABLE 3.—*Visibility (miles and fractions) C.S.T.*

Station	7 a.m.	10:30 a.m.	Local noon	2:30 p.m.	7 p.m.	Lowest any time
Bismarck	12	4	4	5	6	3
Devils Lake	3	3	3	2	8	2
Moorhead	10	1	½	½	10	½
Duluth	12	10	1	7	12	1
Pembina	5	0	0	¼	1	Zero
Huron	10	⅛	0	¼	2	Zero
Alexandria, Minn	8	2	½	¼	1	Zero
St. Paul	10	7	4	1	1	1
Valentine	4	½	½	¼	4	½
Sioux City	15	¾	¼	0	¼	Zero
Adair, Iowa	12	10	2	½	⅛	⅛
Davenport	8	8	8	2½	⅕	⅕
Kansas City	12	12	12	12	1	1

The damage by wind, dust, and electrical discharges over the several States will never be ascertained. For South Dakota the loss is estimated to be several millions of dollars, for one must take into account the structural damage to buildings, leveling of fences, the scattering of hay and fodder stacks, the damage to highways, soil erosion, and injury to winter crops.

Spectacular becomes a weak adjective when applied to this storm. It was awful, terrifying—the howling winds and a darkness that turned the midday into night, will never be forgotten by residents of the State.

COMMENTS FROM WEATHER BUREAU STATIONS

Bismarck.—We had a maximum wind velocity of 50 miles per hour on Sunday forenoon and considerable damage resulted in this vicinity.

Kansas City.—This storm did not arrive here until late in the afternoon of the 12th. Dust first observed by airport observers about 3:30 p.m. It became thicker late in the evening; the lowest visibility occurring at about 9:30 p.m. when it was about three fourths of a mile.

Valentine.—The total precipitation at Valentine from August 29 to November 12 was 0.53 inch. One moment I could see an object about one half mile away and in another moment could not see it. Occasional breaks of 1 or 2 seconds in the dust clouds indicated a clear sky but dense dust obscured the sun.

Des Moines.—A gale and intense dust storm on the 12th made lights necessary in houses and on automobiles in the midafternoon. Corn shocks were blown over and straw stacks damaged; considerable wheat was blown out or covered. Fall-plowed soil drifted. Damage occurred to buildings and trees. Half the corn was blown onto the ground making it impracticable to use husking machines.

Minneapolis.—High winds Sunday, November 12, 1933, caused considerable damage and much soil blowing in the south portion of the State.

Lincoln.—The weather continued dry, with gales of dense dust Sunday, November 12, 1933.

Sioux City.—The horizontal visibility decreased from 15 miles at 7 a.m. to one fourth mile at 12:26 p.m. The ceiling and visibility were both recorded as zero at 2:30 p.m. when objects could not be seen by pedestrians at a distance greater than 50 feet. Obstruction to vision of 100 feet or less obtained from 1 p.m. to 3 p.m. when houses and buildings were artificially lighted. At 6:45 p.m. the visibility was one fourth mile, following which there was a gradual improvement and by 10:30 p.m. it was extended to 8 miles.

THE DUSTFALL OF NOVEMBER 12–13, 1933

By Eric R. Miller

[Weather Bureau, Madison, Wis., February 1934]

Meteorological observations are now so numerous, on account of the development of the weather service along airways, and the addition of upper-air observations with pilot balloons and airplanes, that it is possible to fix the origin of the Buffalo dustfall of November 13, 1933, with a high approach to certainty.

The state of the atmosphere at the time the dust was precipitated at Buffalo is shown graphically on the weather map, figure 2, November 13, 8 a.m., prepared from simultaneous observations throughout the United States and Canada. This map was very kindly furnished by Mr. John Patterson, Director of the Canadian Meteorological Service, who has added the track of the center of the cyclone that then occupied the region just west of the Appalachian Range from Quebec to the East Gulf States.

The important feature of this map is the wide-spread northwest wind, extending from the wind-shift line westward to the plains. It was the underrunning by this wind of the southwest wind, shown along the Atlantic seaboard, but previously occupying the region west of the mountains, that produced the fall of rain and snow (shown by horizontal hatchures) that brought down the dust.

Figure 1, November 12 (8 a.m.), shows the atmospheric conditions just 24 hours earlier than those of figure 2. The center of the cyclone was then near Winnipeg, the pressure gradient very steep, and the winds correspondingly strong.

The hourly airways reports show that while the winds were light to moderate in the early morning, the velocity steadily increased, and by 1:30 p.m., fierce gales with velocities of 45 to 63 miles per hour were raging over a wide area between Bismarck, N.Dak., and Kansas City, Mo., and between the Badlands of South Dakota and Sand Hills of Nebraska, and the Mississippi River where it bounds Minnesota and Iowa.

The strength of the wind was so great that not only dust was whirled up from the roads, but also gravel and pebbles, and fall-plowed fields marked by clouds of drifting soil. An airplane pilot at Omaha found the top of blowing dust only on ascending to 9,000 feet, while at the ground the air was so thick that objects 50 to 100 feet away could not be seen.

It is interesting to speculate whether the volcanic materials found at Buffalo were transported directly from Alaska, especially as this storm is shown by weather maps to have skirted along the Alaskan-Pacific coast. This, however, is negatived by reports from the weather-observing stations along the northwestern border. Pembina, Devils Lake, and Williston, N.Dak., report no dust or haze at any time on the 12th, and at Bismarck, blowing dust was reported at only 1 hour. The western and southern limits of the area of deflation are indicated by reports of no dust at Miles City and Havre, Mont., Sheridan and Cheyenne, Wyo.; for only 3 hours at Dodge City, Kans., and none at all at Wichita, Kans.

The dust cloud was carried mostly southeastward by the storm winds, but with much spreading toward the East and South. The hourly reports transmitted by teletypewriter along airways enable one to follow the progress of the dust cloud through the afternoon and night of the 12th, and in the Southeastern States on through the whole of the 13th. Isochrones, for every fourth hour, of the front of the dust cloud, are shown in the inset in figure 2.

The wings of the dust cloud were markedly thinner than the middle. The meteorological airplane flight at Dallas, Tex., November 13, 1933, at 5 a.m., E.S.T., rose through a dusty stratum 5,500 feet thick before emerging into clear air above, and the temperature-altitude graph shows bend-points very similar to those observed at Omaha on the previous morning. The airways observer at Buffalo reported "Dark in the northwest, thick dust approaching from west" at 10:02 a.m., E.S.T., on the 13th, while at Mercer, Pa., the visibility was already down to 1 mile on account of dust at 9:42 a.m. Jamestown, N.Y., also reported dust in rain about 9 a.m. At Rochester housewives complained of muddy rain on their Monday washings hung out to dry. At Syracuse the rain-precipitated dust was afterward found on windows and automobiles.

The airways observers at Bellefonte, Pa., observed dust with mist and rain between 3:15 and 4:35 p.m., while at Watertown, N.Y., the dust cloud itself was observed to strike the town at 3:30 p.m. At Binghamton no cloud was observed, and the continuously operated air-filter paper at the laboratory of the Agfa Ansco Corporation failed to show dust. At Alexandria Bay, N.Y., the observer noted discolored rain falling at 2 p.m. In Vermont the regular observers did not note the phenomenon, but received an inquiry about "brown snow" from the eastern part of the State.

The denser middle of the dust cloud reached Tennessee early on the morning of the 13th, reducing the visibility to one quarter mile at Nashville at 8 a.m. and to one fifth mile at Chattanooga at noon. The onward drift carried the dust over Mississippi, Alabama, and Georgia during the afternoon and night of the 13th, with visibilities as low as 2 to 5 miles as late as 11 p.m.

HUMIDITY

Winds from the plateau beyond the Rocky Mountains on descending the eastern slopes of the ranges were warmed by compression and their relative humidity correspondingly decreased. The reports of the airways observers show this drying beginning early in the morning of the 12th at Denver, Cheyenne, and Sheridan. The greatest dryness, curiously enough, was not at the base of the mountains, but at Kansas City, where the relative humidity fell to 10 percent at 8 p.m. of the 12th.

This fact hints that the subsidence and heating continued as the air mass moved away from the mountains, on account of the divergence that has already been noted, the spreading of the lower layer being supplied by descent of air from above. The extraordinary dryness persisted in the dust-bearing air mass as it drifted southeastward all the way to the Atlantic. At midnight of the 12th the relative humidity was 21 percent at Wichita, 20 percent at Terre Haute; at 4 a.m. of the 13th, 28 percent at Little Rock, 30 percent at Louisville; at 8 a.m., 36 percent at Little Rock, 54 percent at Elkins; at noon, 31 percent at Jackson, Miss., 40 percent at Mobile, 36 percent at Knoxville, 39 percent at Lewes, Del., and 53 percent at Savannah, Ga., and Wilmington, N.C.

Figure 1. Weather Map, 8 a. m., November 12, 1933, when dust was blowing up from the ground on the northern Great Plains

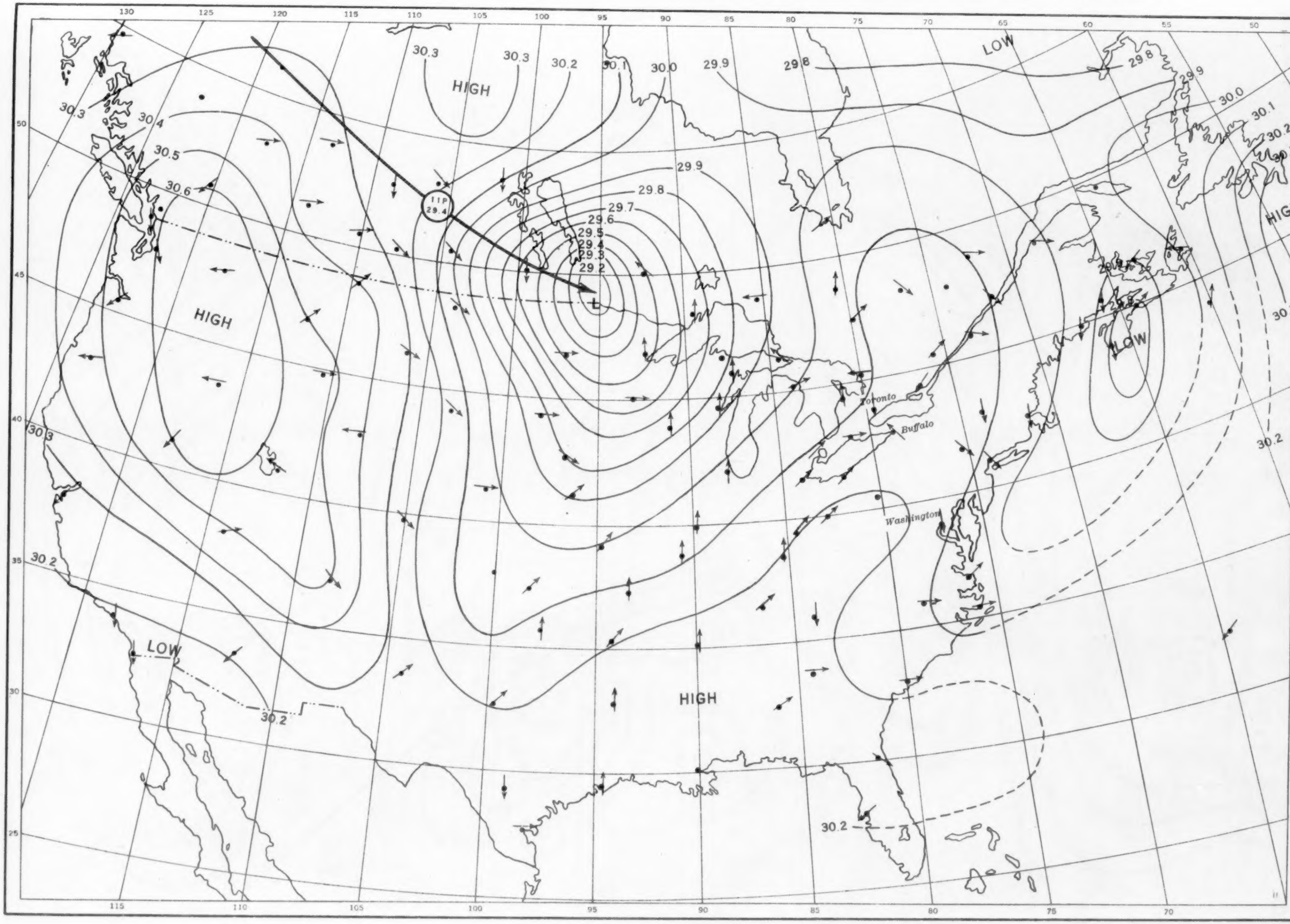
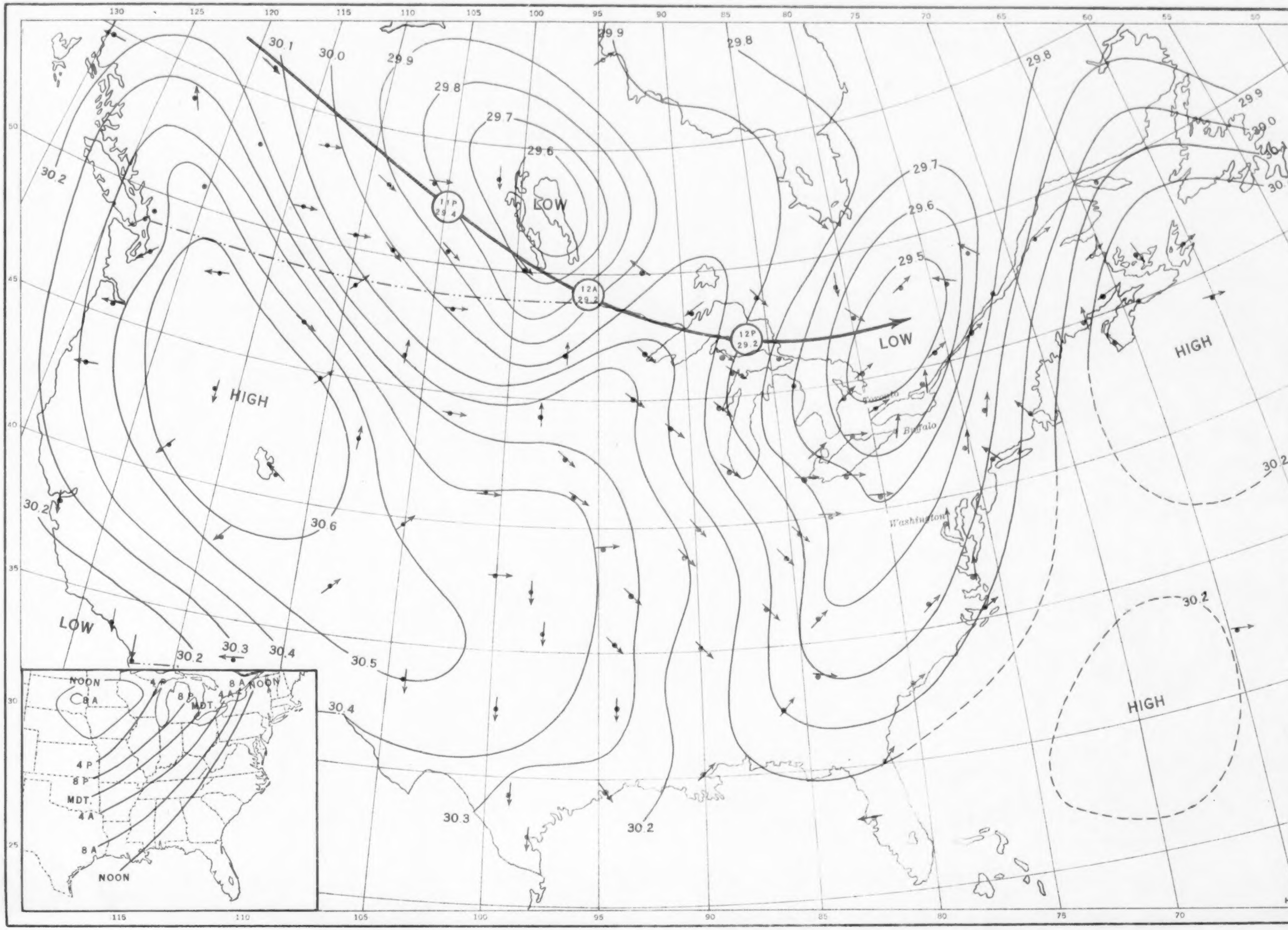


Figure 1. Weather Map, 8 a. m., November 12, 1933, when dust was blowing up from the ground on the northern Great Plains

Figure 2. Weather Map, 8 a. m., November 13, 1933, when dust cloud stretched from eastern Ontario across western New York, the Ohio Valley, the southern Appalachians, and the Gulf States to Texas.



(Inset) Isochronal lines of the dust cloud, from reports of airways observers (E. S. T.) of the U. S. Weather Bureau

COLLECTION AND EXAMINATION OF DUST

Wind-borne dusts are of interest to geologists for the light they throw on the rate of deposition of loess, and on the character of minerals supposed to be of aeolian origin. For the solution of these problems it is desirable to know the quantity of dust precipitated per unit area, especially in rain and snow, and the relative quantity of different sizes. The best plan for making this determination is to measure off a square yard or square meter, and brush up the dust, if dry, or to shovel up all the dust-bearing layer of snow or sleet. Rain with dust is best taken from the ordinary Weather Bureau rain gage.

To determine the soluble materials in a dustfall, and these are important in estimating how fast potassium and other natural fertilizers are being added to eastern soils by air transport from the arid West, it is essential not to filter the rain and melted snow, but to evaporate them.

The samples collected for weighing and sizing, will also serve for mineralogical and chemical analysis, if carefully handled. The identification of diatom tests, and other organic materials can also be made on the same material. For the detection of viable spores, it is best to notify specialists in plant pathology, so that they may go into the field before the dustfall disappears and secure uncontaminated material for incubation.

LITERATURE THAT MAY BE CONSULTED

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(3) Winchell & Miller. The dustfall of March 9, 1918. Am. Jour. Sc., v. 46, 1918, pp. 599–609, and v. 47, 1919, pp. 133–134.

(4) ——— The dustfalls of March, 1918. Mo. Wea. Rev. 1918, v. 46, pp. 502–506.

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PETROLOGY OF THE GREAT DUSTFALL OF NOVEMBER 13, 1933

By A. E. ALEXANDER

[150 Guilding Avenue, Buffalo, N.Y.]

Snow falling at Buffalo on the morning of November 13, 1933, was observed to be discolored. The depth of snow on the ground, including previous falls, was about 5 inches, but in order to avoid contamination only the top few inches of fresh snow was collected. This was melted, the liquid filtered, and the residue mounted in Canada balsam, and then examined, with polarized light, with the microscope.

The organic and inorganic substances present are:

Volcanic glass	Hornblende
Quartz	Diatom tests
Feldspar	Spores
Mica	Pollen
Tourmaline	Vegetable fibers
Zircon	

There are two kinds of volcanic glass in the dust. In transmitted light, one variety is colorless and contains inclusions, which may be either liquid or gaseous. The other variety is black, and suggests basaltic glass. The feldspar is unaltered. It consists of orthoclase, microcline, and plagioclase feldspar. These mineral grains are angular to subangular in appearance. The quartz and feldspars examined from the Buffalo dustfall are glassy clear and are not at all stained by iron oxide as were those in the Madison dustfall of 1918, concerning which Winchell and Miller (1) say "both the quartz and the feldspar are stained by limonite and hematite, and this condition seems to pervade the fragments so thoroughly that it is a condition of long standing." The mica is mainly muscovite, although a green variety present probably represents some form of biotite. Brown and blue colored tourmaline are present, as is colorless zircon. Both of these minerals are distinctly euhedral.

The hornblende is light green and possesses the characteristic prismatic cleavage of the amphiboles. While most of the mineral grains present are subangular to angular, a few minute, undetermined, colorless grains, showing abnormal berlin blue interference colors under crossed nicols suggestive of vesuvianite or zoisite, are distinctly subangular or subrounded.

Winchell and Miller (2), speaking of the Madison dustfall of 1918, state that "microscopic measurements of the size of the particles show that they range from about 0.003 mm to 0.1 mm but a surprisingly large percentage falls within much narrower limits, namely, 0.008 to 0.025 mm." The range of the diameters or lengths of the Buffalo dust particles varies from 0.005 to 0.5 mm, while a large percentage of the dust averages 0.02 mm. A little of the dust was spread out on a black sheet of paper and it was seen that a few colorless grains were just large enough to be visible to the naked eye.

About 10 percent of the entire sample consists of organic matter. According to Mrs. Imogene Robertson, assistant curator of biology at the Buffalo Museum of Science, the organic matter consists of spores of microfungi, ferns, mosses, and encysted protozoans. The spores seen present a variety of forms and shapes. Some are spherical, others ovoid, still others distinctly elongated. These varishaped spores are some smooth, some pitted, and a few distinctly spinous.

According to Winchell and Miller, the Madison, 1918, dustfall consists mainly of feldspar, quartz, and diatom tests, with minor amounts of other constituents, and Twenhofel (3) suggests that the place of origin was the semiarid regions of New Mexico, Arizona, and adjacent States. The assemblage of organic and inorganic matter which composes the Buffalo grit, however, is characteristic for the most part of dried-up playa lakes and ponds or flood-plain areas.

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MOUNT WASHINGTON OBSERVATORY, N.H., PROGRESS REPORT

By SALVATORE PAGLIUCA, Chief Observer

[Presented to the ninety-third meeting of A.A.A.S., Boston, Mass., December 27, 1933]

The Mount Washington Observatory (fig. 1) is going through its second year of operation. The unique history of this contemporary undertaking is outlined in a paper presented at the fourteenth annual meeting of the American Geophysical Union (Apr. 27, 1933) by R. S. Monahan and S. Pagliuca. (Transactions A.G.U., pp. 85–88.)

Meteorological observations and radio experimenting were started in October 1932 and have been carried on continuously for the past 14 months. The work, originally started for the purpose of cooperating with the second international polar year, is now embracing wider aims, particularly the resumption of the valuable series of observations carried on by the United States Signal Service from 1871 to 1887 the year around and for the following 5 years during the months of July–September only, following the famous Huntington-Hitchcock expedition of 1870–71.

With the increasing importance of a better knowledge of the upper air from the dynamic standpoint, the necessity of high-level observations is evident. Present means of upper-air observations are generally restricted to conditions favorable to the particular method used. In the case of mountain stations, once the local topographical influence on meteorological factors have been determined by means of auxiliary observations with airplanes, kites, balloons, etc., stations at the 2,000-meter level or higher would undoubtedly furnish invaluable data on the upper air. Mount Washington (1,915 m) favorably located in a region of frequent general storms, promises to yield data of a value commensurate with the necessary efforts and expenses.

The summit observatory is supplemented by two comparison stations one at 610 meters in Pinkham Notch and another at 795 meters at the base station of the Mount Washington Cog Railway; both equipped with standard and self-recording instruments.

During the months of June–September data on temperature, humidity, wind, precipitation, and cloudiness were gathered at the various huts of the Appalachian Mountain Club and Dartmouth Outing Club. The Greenleaf hut at about 1,250 meters on the west slopes of Mount Lafayette was particularly well equipped for complete observations.

Mr. S. P. Fergusson made his headquarters at the observatory last summer (1933) for his important aerological work by means of kites and airplane flights to determine the influence of the mountain on free air conditions. Many students and meteorologists have visited the observatory and availed themselves of the opportunity offered by the comfortable quarters, and expressed deep interest in the work.

The data obtained during the past 13 months of observations are now being tabulated by the observatory staff in accordance with international practice. It is expected that data and results obtained on Mount Washington will be published in full at an early date. It is also hoped that the prompt and regular availability of daily weather reports from the summit may be of some value to the forecaster.

Because of the peculiar difficulties experienced in obtaining current and special observations on Mount Washington, an outline of the methods used to secure reliable and continuous records may prove of value.

Mountain meteorology in this country deserves the best encouragement in the light of modern instrumental methods and theoretical trends, and Mount Washington, the oldest mountain station in the world, located on the stormiest peak ever studied continuously, is trusting to the cooperation of interested individuals and organizations to continue its contribution to meteorological and allied sciences.

To Dr. C. F. Brooks, director of the Blue Hill Observatory, Mr. Henry S. Shaw, Mr. S. P. Fergusson, the Meteorological Department of the Massachusetts Institute of Technology, and many other supporters the observatory staff: Joseph B. Dodge, director; Alexander A. McKenzie, summit radio operator; Salvatore Pagliuca, Wendell F. Stephenson, and Robert G. Stone, summit observers, are particularly indebted for having made possible the realization of this project.

Atmospheric pressure.—A mercurial barometer for direct reading, a mercurial barograph, and an aneroid barograph are used for atmospheric pressure measurement. The dynamic action of the wind and other causes inherent to the location of the station are frequently responsible for pronounced pressure oscillations which in some instances have reached the order of 0.2 inch on the recording instruments. These actions are being systematically studied in order to obtain quantitative data.

An attempt to determine the dynamic action of the wind on the mountain slopes was made last May with five well-equipped stations operating for 10 days on the west and east sides and intercommunicating by telephone and radiotelephone. The unfortunate lack of atmospheric action prevented obtaining the desired results, but simultaneous cloud observations and various other data were obtained. Plans are laid out for repeating this experiment very shortly, and perhaps more than once this winter, with the cooperation of several hardy volunteer observers.

Wind velocity.—The first real effort to obtain a continuous record of wind movement on Mount Washington was made last winter (1932–33), when the conventional type of cup anemometer was replaced with an electrically heated anemometer of special design, electrically connected to a weekly recorder. This instrument was installed on the observatory building, 8 feet above the roof ridge, and consisted of a stationary heater of the type commonly used in electric stoves and a cup-wheel rotor. Heat was applied during the long and frequent periods of rime and ice deposition (fig. 2). Early experiences proved the insufficiency of this design and the necessity of improvements. A new and improved anemometer was designed and built with the aid of the Permanent Science Fund of the American Academy of Arts and Sciences. The heater is totally enclosed except for a small air gap around the shaft. A double-circuit heating device of 700 watts maximum capacity permits the application of heat according to requirements. Other features are vacuum contacts for electrical recording, a special connection box, ball bearings, and an all-around sturdy and accurate mechanical construction. The velocity characteristic of the instrument is far from being ideal, but its chief purpose is to record with the accuracy of modern standardization methods, rime forming winds of superhurricane force.

FIGURE 1.—Mount Washington Observatory, after a storm. Members of staff inspecting heated anemometer, radio antenna, and instrument shelter. Cumulus clouds in the background are 1,000 feet below the summit. (Photo by W. H. Pote.)

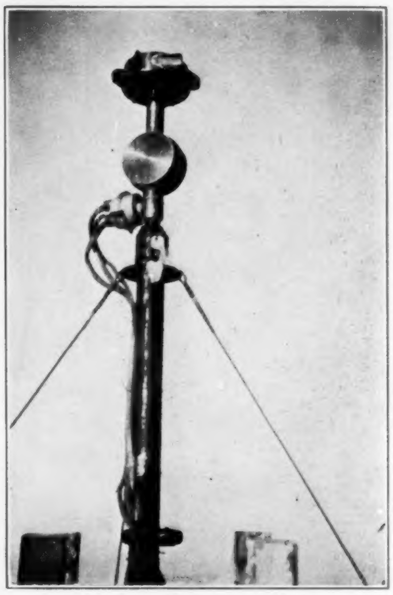

FIGURE 2.—Heated anemometer no. 2, with vacuum contacts and especially rugged construction.

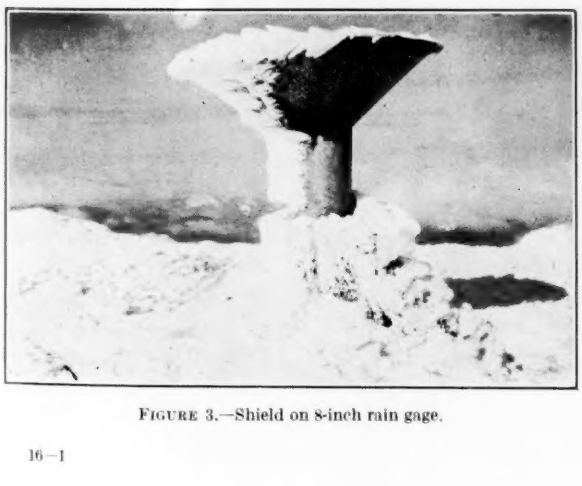

FIGURE 3.—Shield on 8-inch rain gage.

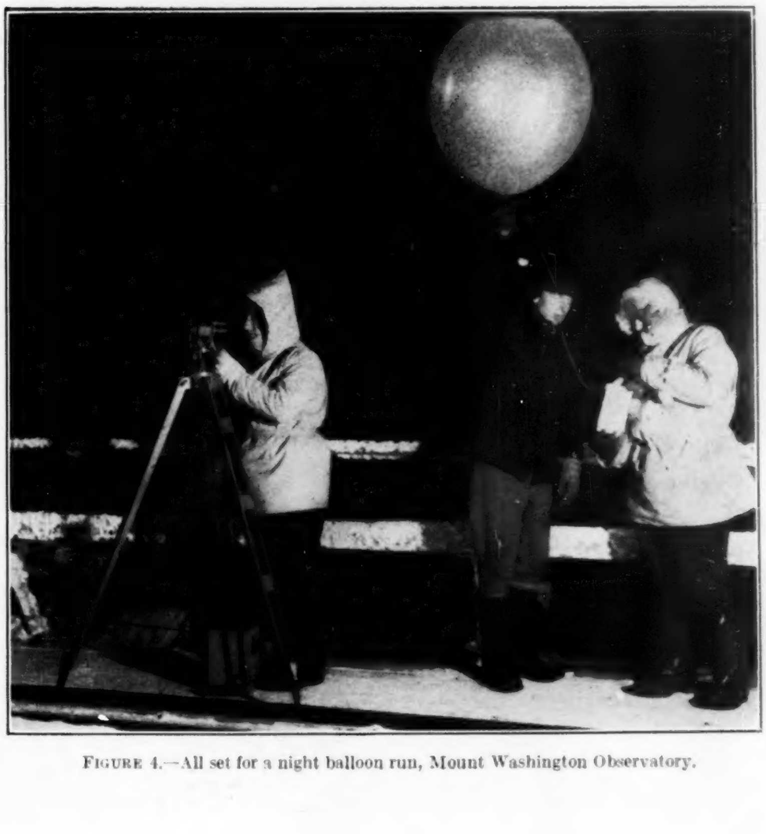

FIGURE 4.—All set for a night balloon run, Mount Washington Observatory.

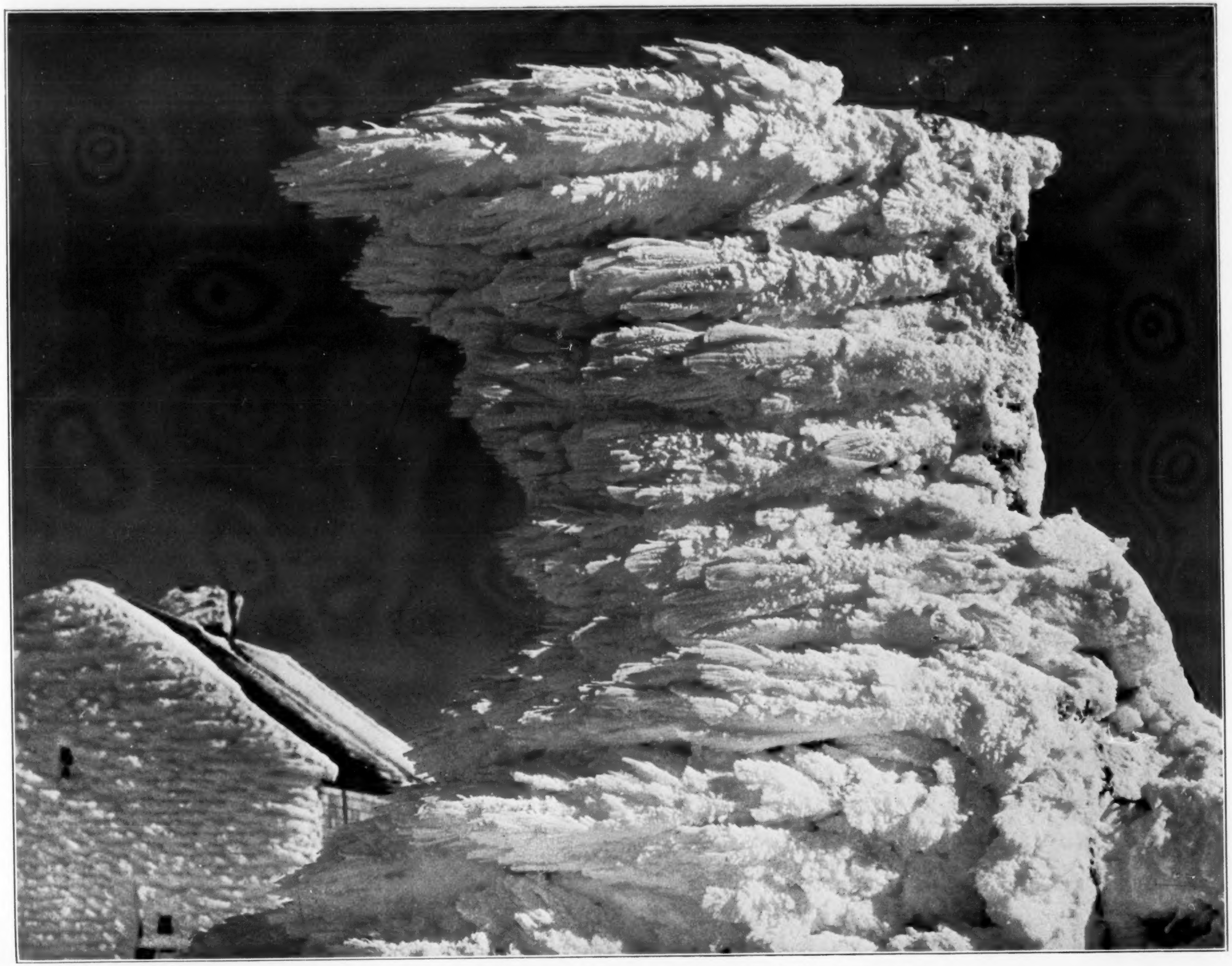

FIGURE 5.—Rime from a single storm, October 1932, on pyrheliometer post. (Photo by Harold Orne.)

The anemometer was recently standardized at the United States Bureau of Standards and is to be exposed on a structure on top of the summit tank at an actual height of 10 meters above the geographical summit. The heat is supplied from the observatory 100 meters distant by means of lead-covered 20-conductor cables carrying 110 volts, direct current. A service shelter on the tank is electrically illuminated and connected by telephone to the observatory. Although the recording is obtained electrically at the observatory building, a frequent walk to the instrument is necessary, particularly under extreme conditions.

In connection with the electric heating of the wind-measuring instruments, and in order to assure a more accurate record of the duration of rime deposition, an ingenious device has been developed and called rime detector. It consists of a photoelectric cell which is acted upon by the light of an ordinary flashlight bulb, reflected by a small mirror exposed to the elements. As the rime starts forming on the mirror the reflected beam of light is weakened and the photoelectric cell, by means of an amplifier and a relay, acts as an alarm circuit. This circuit could be made to start automatically the power plant, but manual operation is preferable during the winter. A somewhat less reliable device, but with reverse action, is being built on the well-known principle of the thermo-hygrograph on the assumption that rime generally starts forming at below freezing temperature and 100 percent relative humidity.

Experiments are being conducted with a hot-air anemometer in order to develop a more economical means of heating the wind-measuring instruments, and a Pitot static tube is available for comparison readings under special conditions.

Wind direction.—The necessity of obtaining a reliable and continuous record of wind direction suggested the use of wind vanes of special design, electrically heated at the collar so as to be let free to rotate during rime-forming periods, and equipped for mechanical and electrical recording. In order to reduce rime accumulation the tail end of the vane only is being used, and various types of vanes are being tried. The over-all length is about 25 inches. Two of these vanes are being exposed, one at the end of the trestle and another on the summit tank, to avoid faulty wind-direction readings due to the influence of the summit buildings.

Precipitation.—Precipitation on Mount Washington generally occurs with high winds, which are influenced in direction and intensity by the topography of the summit and the presence of the summit buildings. Hence consistent results could only be obtained by exposing a number of gages at various points in order to average possible disturbing effects. Moreover, it was found necessary to equip the gages with shields in order to reduce the direct disturbing influence of the wind. After a series of experiments, in which the actual effect of the shield on the wind was studied by observing the orientation and length of rime feathers forming around it, a simple type of funnel-shaped shield with 45° angle of deviation and 30 inches upper diameter, was found satisfactory and standardized for all purposes (fig. 3). Four shielded gages located at cardinal points and one unshielded gage for comparison purposes are now being used. Wherever necessary, gages are slanted so as to make the upper surface parallel with the mountain slope. Collection is made twice a day, oftentime with considerable difficulties. Drifting snow seriously complicates the precipitation measurements. A close investigation of this problem is being conducted in order to determine as closely as possible the amount of drifting snow that is blown in the gages under different conditions of wind direction and velocity and the type of snow on the ground.

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There seems to be hardly any relationship between the amount of snow caught in the gages and the amount of snow actually staying on the summit ground for any length of time. The strong westerly winds blow a huge amount of snow on to the eastern slopes and into the western ravines, where it stays until early summer. This drifting action makes it very difficult to determine even approximately the amount of snow on the ground. Drifts 10 to 15 feet high may alternate with almost bare spots. The amount of snow on the ground is given as the average of a number of depths obtained at points where drifting is absent or negligible, and special mention is made of size and frequency of drifts.

Rime deposition.—Lacking a standard expressing quantitatively the huge amount of rime deposition on the summit, only a record of duration and intensity of deposition is being kept with particular reference to the average rate of growth and maximum length of rime feathers on exposed objects. Feathers longer than 5 feet have been observed building against the wind (fig. 5).

For convenience we have agreed to call *rime* all depositions having a well-defined featherly appearance and resulting from cold fogs (or clouds) generally blown by westerly winds; and *rough frost* all desposition deriving from wet fogs (or clouds) at slightly below freezing temperature blown by winds of general southerly directions. Rough frost has the appearance of ice masses and has a much higher specific gravity than rime.

During the winter, fall, and spring months the station is more than 50 percent of the time in rime-forming fogs (or clouds). It therefore is favorably located for investigations on the important problem of ice formation on aircraft and an effort will be made this winter (1933–34) to establish a standard by which rime deposition can be recorded in a way similar to precipitation.

Air temperature.—Standard mercurial and spirit thermometers are used for recording current and extreme temperatures, and thermographs of the Bourdon tube type are used for continuous temperature records. These instruments with relatively little attention give satisfactory results under severe conditions.

Relative humidity.—The sling psychometer and hair hygrometer are being normally used for the measurement of relative humidity. The unsatisfactory results obtained from these two instruments at low temperature and rimy conditions suggested to the meteorological department of the Massachusetts Institute of Technology and the Blue Hill Observatory a concerted experimental attack on this problem. Simultaneous tests by means of a dew-point indicator, heated Assmann, sling psychrometer, hair hygrometer, sampling of air by means of previously exhausted bottles, Aitken counter, and Owens counter, have been made with the utmost care. These various methods show a more or less degree of consistency under somewhat favorable conditions. Dr. H. C. Willett has kindly agreed to discuss the preliminary results of these tests.

The development of a reliable and convenient instrument for the determination of the dew point and relative humidity at low temperature and rapidly variable conditions is a necessity in view of the developments of aviation, polar, and mountain meteorology.

Clouds observations.—Detailed cloud study is being made in accordance with international practice. Nephoscopic observations are being made regularly at least every 3 hours. The height of clouds is obtained by

means of pilot balloons and occasionally by means of double nephoscope and double theodolite observations. A systematic study will be conducted by means of multiple nephoscope observations to determine the influence of the mountain on the height of medium and perhaps high clouds.

Aerologic observations.—Whenever conditions permit, hydrogen-inflated pilot balloons with 180 meters per minute ascensional rate are released and followed with a theodolite (fig. 4). A complication is being introduced in the computation of the ascensions where the initial elevation angle is negative due to downdraft effect. When enough double theodolite ascensions shall have been made, it will be possible to work out a scheme for calculating with a fair degree of accuracy the position of the balloon during the downward run.

So far more than 200 pilot balloon ascensions have been made. In one instance a balloon released 100 yards below the windward side of the summit followed nearly the same downward course of a balloon released from the summit.

Solar radiation.—Total solar and sky radiation on a horizontal surface is being recorded by means of an Eppley-type pyrheliometer bulb (fig. 5, right, top) connected to an Engelhard recorder. One of these bulbs was continuously exposed to the full severity of the elements last winter (1932–33), and was undamaged until overloaded by lightning last spring. Direct solar observations are made on clear days by means of a thermopile. All the solar apparatus was loaned and installed by the Eppley Laboratory, Inc., of Newport, R.I.

Aurora borealis.—The frequency and various developments of auroral displays are accurately recorded on star charts supplemented by theodolite measurements.

Optical phenomena.—Optical phenomena are accurately recorded in time and dimensions. Particular emphasis is given to coronae and halo measurements. Unusual visibility and time and character of sunrises and sunsets are also recorded.

Snow temperature.—Various tests of snow temperature at various depths have been made and correlated with variations in the air temperature.

Snow and rime sediments.—Samples of snow and rime sediments were taken and sent to the Massachusetts Institute of Technology for analysis.

Some meteorological data on Mount Washington and comparison stations for 1933

	Monthly mean temperature in degrees F.			Monthly precipitation in inches		
	Mount Washington	Pinkham	Concord, N.H.	Mount Washington	Pinkham	Concord, N.H.
January	12.6	24.2	30.8	4.59	3.03	1.95
February	7.0	20.8	27.6	5.58	3.75	3.27
March	9.2	22.7	31.1	6.90	7.80	5.23
April	25.4	36.9	43.0	9.45	8.07	6.36
May	37.0	50.7	57.8	3.66	3.33	2.44
June	46.1	59.2	66.9	5.36	2.87	1.25
July	49.6	60.6	69.1	4.63	6.36	3.25
August	49.7	59.3	67.4	10.13	7.76	6.01
September	42.2	54.2	60.9	5.04	2.74	4.54
October	29.7	42.0	48.4	4.64	6.77	4.90
November	12.2	26.4	33.1	5.69	1.89	1.50
December	5.0	14.6	20.0	4.11	4.97	2.76

	Average hourly wind movement in miles per hour		
	Mount Washington	Blue Hill	Portland
May	35.8	16.9	9.3
June	32.1	12.8	8.7
July	26.4	12.9	7.4
August	24.8	13.0	7.6
September	34.2	10.8	7.5
October	41.0	14.1	9.3
November	52.0	17.0	9.3
December	59.0	19.2	9.2

Maximum pressure, 24.20 inches (S.L. 30.75 inches) Oct. 21.
Minimum pressure, 22.51 inches (S.L. 28.74 inches) Mar. 9.
Maximum temperature, 71.0° F. June 28.
Minimum temperature −46.2° F. Dec. 29.
Maximum wind velocity, 164, miles per hour, recorded on Apr. 5.

BIBLIOGRAPHY

C. FITZHUGH TALMAN, in charge of Library

RECENT ADDITIONS

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies:

Abbot, Charles Greeley.
Sun spots and weather. Washington. 1933. 10 p. diagrs. 24½ cm. (Smithsonian miscellaneous collections. v. 87, no. 18.) (Roebling fund.)

Acta phaenologica.
International phenological journal . . . onder redactie van het bestuur der Nederlandsche phaenologische vereeniging. Eerste deel. 1932. 's-Gravenhage. 24½ cm.

Brooks, Donald Bane.
Psychrometric charts. Washington. 1933. 3 p. 27 cm. (U.S. Bureau of standards. Miscellaneous publications, no. 143.) (At head of title: U.S. Department of commerce. Daniel C. Roper, secretary. Bureau of standards. Lyman J. Briggs, director.)

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Records. Vladivostok. No. 2 (IX). 1932. 24½ cm. [Author and title in Russian and English.]

Jinsen. Meteorological observatory.
Upper-air current observations. 1–2. 1930–31. Zinsen [Japan.] (Tyôsen.) 26 cm. n.d.

Monahan, Robert Scott.
Mount Washington reoccupied: The experiences of a scientific expedition upon the highest mountain in New England, 1932–33. Brattleboro. 1933. 270 p. front., illus. (maps, plates, ports., facsim). 21 cm. (This expedition served as a cooperating unit in a world-wide network of meteorological stations known as the Second international polar year.)

Tunis. Service météorologique.
Tableau des pluies de décembre 1932, janvier et février 1933. Tunis. 1933. 7 p. map (fold.) 24½ cm. (Bulletin Direct. gén. agric., comm. et colon. 2e trim. 1933.)

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Physical optics. 3d ed. New York. 1934. xvi, 846 p. front., illus., diagrs. 22 cm.

SOLAR OBSERVATIONS

SOLAR RADIATION MEASUREMENTS DURING JANUARY 1934

By IRVING F. HAND, Assistant in Solar Radiation Investigations

For a description of instruments employed and their exposures, the reader is referred to the January 1932 REVIEW, page 26.

Beginning with this month there are included in addition to the intensity measurements heretofore given in the REVIEW, the computed atmospheric turbidity factor, β, and the water-vapor content, w, expressed as the depth of the water in centimeters that would be obtained were all the vapor precipitated. The value of β is computed by the method illustrated in the REVIEW for March 1933, volume 61, page 83, table 2 [1] where the method of computing w is also shown. Dr. Herbert H. Kimball, of the Blue Hill Meteorological Observatory, states, relative to these measurements:

> No great accuracy can be claimed for the values from Blue Hill, for the reason that the thermopile used to obtain a continuous record of the radiation intensities is not well protected from the wind. As a result the record trace is often quite feathery in appearance. The effort is now being made to afford better protection of this instrument from the wind.

In obtaining the value of the precipitable water, w, a deduction of 1 percent of the solar constant, or 0.01 from the value of $I_{w=0}-I_m$ has been made, which is Fowle's approximate value of the absorption by the permanent gases of the atmosphere.[2]

The importance of extreme accuracy in the radiation measurements will be appreciated from the fact that an error of 0.01 gr. cal./min./cm^2 in the measurement of I_m, I_y, or I_r, may cause an error of 0.005 in the computed value of $\beta_{I_m-I_r}$, and of at least twice that magnitude in $\beta_{I_y-I_r}$, with corresponding errors in $I_{w=0}$ and $I_{w=0}-I_m$.

Table 1 shows that solar radiation intensities averaged above normal for January at Washington and Madison, and close to normal at Lincoln.

Table 2 shows an excess in the total solar and sky radiation received on a horizontal surface at Chicago, New York, La Jolla, and New Orleans, and a deficiency at all other stations for which we have normals.

Polarization measurements obtained on 3 days at Washington give a mean of 61 percent with a maximum of 63 percent on the 31st. These are close to normal values for the month. No polarization measurements were obtained at Madison during January because Lake Mendota was continuously frozen and the ground intermittently covered with snow.

[1] Please see the REVIEW for January 1933, 61:4, where it is stated that for the transmission coefficients of the yellow and red glass screens the values 0.882 and 0.871 should be used instead of 0.889 and 0.878, respectively, as given in the table.

[2] See Smithsonian Meteorological Tables, 5th revised edition, 1931, table 111, and Fowle's estimate of the ozone absorption in the visible spectrum, page lxxxv, of the same tables.

TABLE 1.—*Solar radiation intensities during January 1934*

[Gram-calories per minute per square centimeter of normal surface]

WASHINGTON, D.C.

Date	8 a.m. 75th mer. time	Sun's zenith distance 78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon Local mean solar time
		Air mass A.M. 5.0	A.M. 4.0	A.M. 3.0	A.M. 2.0	*1.0	P.M. 2.0	P.M. 3.0	P.M. 4.0	P.M. 5.0	
	e mm	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	e mm
Jan. 2	3.45		0.82								3.15
Jan. 10	3.99	0.66	.77	0.88							3.63
Jan. 11	3.63	.73	.83	.97	1.30		1.28	1.09	1.00	0.88	3.15
Jan. 16	4.17				1.26			1.22			2.87
Jan. 18	1.78		.90								1.88
Jan. 20	2.74				1.21						2.62
Jan. 23	6.02						1.37			.98	6.02
Jan. 24	1.78	.90	.94	1.14							1.78
Jan. 25	2.87	.66	.88	1.00	1.16						4.17
Jan. 30	.66		.89								.56
Jan. 31	.76		.76	.88	1.33		1.30	1.12	.83	.68	1.12
Means		.73	.85	.97	1.25		1.32	1.14	(.92)	.85	
Departures		+.01	±.00	−.05	+.02		+.08	+.09	+.03	+.05	

MADISON, WIS.

Date	8 a.m.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	Noon
Jan. 15	2.87	1.02	1.18	1.32	1.49						2.36
Jan. 16	2.49	1.11	1.25	1.35	1.50			1.35			2.09
Jan. 23	1.96	1.12	1.22	1.32	1.44						1.96
Jan. 25	3.63	1.07	1.17	1.27	1.45			1.30			4.95
Jan. 28	1.96		1.16	1.23							1.19
Jan. 29	.36				1.47			1.31			.59
Means		1.08	1.20	1.30	1.47			1.32			
Departures		+.12	+.15	+.10	+.12			+.16			

LINCOLN, NEBR.

Date	8 a.m.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	Noon
Jan. 8	1.78							1.20	0.95	0.82	2.16
Jan. 13	2.87							1.32	1.18	1.06	2.36
Jan. 16	2.87	0.74	0.91	1.02				1.24	1.06		3.99
Jan. 17	2.87			1.21				1.17	1.03		3.63
Jan. 18	3.15			1.22				1.16			4.57
Jan. 19	2.36							1.15	1.04	.93	3.15
Jan. 20	3.63	.72	.82	1.00	1.24			1.03	.85	.70	5.56
Jan. 22	4.57	.94	1.14	1.29				1.24	1.08	.92	3.99
Jan. 23	3.81		1.06	1.23	1.35						3.45
Jan. 25	.96	.94	1.02	1.22	1.36		1.33	1.10			1.45
Jan. 26	1.68	.93	1.03	1.19	1.45		1.39	1.21			2.62
Jan. 30	1.12		.99								2.29
Jan. 31	2.06	.69	.88	1.12	1.39						3.99
Means		.83	.98	1.17	1.36		(1.36)	1.18	1.03	.89	
Departures		−.10	−.06	−.01	−.01		+.02	+.01	−.01	−.04	

BLUE HILL, MASS.

Date	8 a.m.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	Noon
Jan. 2	7.7									0.91	2.2
Jan. 6	4.2							0.80	0.80		5.4
Jan. 11	3.1						1.26	.92			3.4
Jan. 12	3.3						1.18				3.4
Jan. 16	2.4						1.34	1.02	.91	.81	2.6
Jan. 17	1.9			1.22	1.22						1.3
Jan. 18	1.6			1.32	1.43			1.30			1.0
Jan. 19	3.3								1.00	.84	2.5
Jan. 20	1.9			.78	.72						2.1
Jan. 22	2.1						1.08	.81			2.5
Jan. 24	1.8				1.38		1.38	1.17	1.05		1.9
Jan. 25	1.8			1.05	1.24						2.8
Jan. 30	.5			1.20	1.32						.6
Jan. 31	1.5			1.10	1.20						1.3
Means				1.11	1.22		1.25	1.02	.94	.85	

* Extrapolated.

TABLE 2.—*Average daily totals of solar radiation (direct+diffuse) received on a horizontal surface*

Gram calories per square centimeter

Week beginning—	Washington	Madison	Lincoln	Chicago	New York	Fresno	Pittsburgh	Fairbanks	Twin Falls	La Jolla	Miami	New Orleans	Riverside	Blue Hill	Mount Washington
1934	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Jan. 1	75	68	115	37	75	152	40	7	170	278	329	188	258	77	110
Jan. 8	127	85	121	60	114	84	57	7	167	344	284	249	299	136	118
Jan. 15	209	164	191	161	180	73	130	8	175	323	282	182	300	190	222
Jan. 22	171	172	258	165	135	288	105	8	144	302	340	126	319	149	121
	Departures from weekly normals														
Jan. 1	−75	−61	−74	−42	−27	+10	−49	+1	+13	+33	+37	+38			
Jan. 8	−24	−53	−76	−22	+6	−64	−40	±0	−12	+90	−3	+71			
Jan. 15	+44	+6	−18	+59	+68	−101	+23	−2	−12	+84	−8	−6			
Jan. 22	−5	−11	+19	+50	−13	+78	−5	−6	−43	+42	+16	−49			
	Accumulated departures on Jan. 29														
	−420	−833	−1,043	+315	+238	−539	−497	−56	−378	+1,743	−294	+378			

TABLE 3.—*Total, I_m and screened, I_y, I_r, solar radiation intensity measurements, obtained during January 1934, and determinations of the atmospheric turbidity factor, β, and water-vapor content, w=depth in centimeters, if precipitated*

AMERICAN UNIVERSITY, WASHINGTON, D.C.

Date and hour angle	Solar altitude	Air mass	I_m	I_y	I_r	$\beta_{I_{m-r}}$	$\beta_{I_{y-r}}$	β_{mean}	$\frac{I_{w=0}}{1.94}$ Percentage of solar constant	$\frac{I_{w=0}-I_m}{1.94}$[1] Percentage of solar constant	W
Jan. 10	° ′	*m*	*gr. cal.*	*gr. cal.*	*gr. cal.*						*cm*
2:28 a	19 58	2.90	0.891	0.700	0.591	0.106	0.100	0.103	54.6	0.088	0.4
2:23 a	20 30	2.84	.924	.709	.595	.100	.092	.096	56.5	.096	.2
Jan. 11											
2:12 a	14 26	3.96	.842	.703	.585	.090	.056	.078	51.5	.089	.3
3:06 a	15 14	3.78	.854	.708	.589	.090	.064	.077	52.7	.089	.3
3:01 a	15 54	3.62	.912	.742	.629	.088	.068	.078	53.9	.073	.2
2:57 a	16 26	3.50	.937	.745	.635	.085	.075	.080	54.7	.071	.2
2:49 a	17 29	3.30	1.000	.780	.647	.065	.055	.060	60.1	.098	.4
2:45 a	22 59	3.21	1.011	.785	.650	.065	.053	.059	60.8	.097	.4
1:25 a	28 55	2.06	1.266	.898	.724	.037	.042	.040	75.4	.111	1.0
0:21 a	29 00	2.06	1.272	.904	.729	.037	.042	.040	75.4	.108	1.0
Jan. 24											
3:28 a	14 11	4.02	.925	.727	.619	.068	.063	.065	55.1	.078	.2
3:24 a	14 47	3.86	.968	.732	.623	.046	.065	.056	57.8	.094	.3
2:53 a	19 06	3.04	1.139	.861	.700	.040	.032	.036	67.6	.097	.4
2:32 a	21 48	2.68	1.217	.902	.733	.040	.030	.035	71.6	.098	.5
2:27 a	22 24	2.61	1.244	.908	.739	.030	.034	.032	72.1	.089	.5

Sky conditions at time radiation measurements were made. International meteorological symbols have been employed to designate clouds, wind, and optical phenomena, hz for haze, and v for visibility. ⦶=solar corona.

Jan. 10. P_2O_5 and other fumes and smoke from local blast furnace interfered somewhat. Cu. ended observations. N 2; v 30.

Jan. 11. No clouds; NW 2; v 30–50.

Jan. 24. Local smoke, Ast. at 10:a. NW 3; v 20.

BLUE HILL METEOROLOGICAL OBSERVATORY OF HARVARD UNIVERSITY

[Data furnished through the courtesy of Dr. Herbert H. Kimball]

Date and hour angle	Solar altitude	Air mass	I_m	I_y	I_r	$\beta_{I_{m-r}}$	$\beta_{I_{y-r}}$	β_{mean}	$\frac{I_{w=0}}{1.94}$ Percentage of solar constant	$\frac{I_{w=0}-I_m}{1.94}$[1] Percentage of solar constant	W
Jan. 6	° ′	*m*	*gr. cal.*	*gr. cal.*	*gr. cal.*						*cm*
2:26 p	16 40	3.61	0.840	0.638	0.539	0.084	0.100	0.092	51.4	0.095	0.4
Jan. 11											
2:05 a	19 46	2.93	.875	.672	.552	.100	.100	.100	55.0	.114	1.0

TABLE 3.—*Total, I_m, and screened, I_y, I_r, solar radiation intensity measurements, obtained during January 1934, and determination, of the atmospheric turbidity fastor, β, and water-vapor contents w=depth in centimeters, if precipitated*—Continued.

BLUE HILL METEOROLOGICAL OBSERVATORY OF HARVARD UNIVERSITY—Continued

Date and hour angle	Solar altitude	Air mass	I_m	I_y	I_r	$\beta_{I_{m-r}}$	$\beta_{I_{y-r}}$	β_{mean}	$\frac{I_{w=0}}{1.94}$ Percentage of solar constant	$\frac{I_{w=0}-I_m}{1.94}$[1] Percentage of solar constant	W
Jan. 12	° ′	*m*	*gr. cal.*	*gr. cal.*	*gr. cal.*						*cm*
1:42 a	22 15	2.63	1.084	0.817	0.660	0.068	0.061	0.064	63.0	0.090	0.4
Jan. 15											
0:34 p	26 12	2.26	1.233	.918	.720	.049	.023	.036	75.0	.135	2.8
Jan. 17											
2:05 a	20 41	2.81	1.218	.913	.753	.049	.052	.050	67.0	.062	.2
Jan. 18											
2:07 a	20 10	2.88	1.330	.940	.784	.018	.053	.036	70.4	.048	.1
Jan. 20											
2:12 a	20 35	2.82	.808	.616	.484	.098	.084	.091	57.9	.176	
1:26 a	24 32	2.40	.902	.682	.539	.104	.088	.096	61.9	.160	
0:02 p	27 37	2.15	.726	.590	.451	.187	.107	.147	55.1	.189	
Jan. 22											
0:20 p	27 50	2.14	1.035	.769	.616	.096	.086	.091	64.6	.126	2.0
Jan. 24											
1:57 a	22 52	2.56	1.260	.926	.722	.026	.010	.018	77.4	.145	3.5
1:19 a	25 55	2.28	1.305	.911	.744	.030	.062	.046	72.5	.073	.3
0:07 a	28 31	2.09	1.393	1.006	.810	.032	.030	.031	77.5	.079	.3
Jan. 25											
2:22 a	20 34	2.82	1.095	.798	.638	.044	.088	.066	63.6	.089	.4
1:58 a	23 00	2.55	1.179	.861	.680	.040	.034	.037	72.2	.136	2.5
1:24 a	25 47	2.29	1.207	.866	.681	.040	.037	.038	74.4	.140	3.2
Jan. 31											
2:17 a	23 31	2.50	1.119	.840	.677	.067	.050	.062	66.7	.107	.9
1:12 a	28 05	2.12	1.183	.849	.681	.052	.066	.059	70.9	.117	1.5

[1] Reduced to value at mean solar distance.

Jan. 11, 2 Ci; hz; ⦶; v 7; WSW 3.
Jan. 12, 2 Ci; hz; ⦶; v 6; NW 1.
Jan. 15, 1 Acu, 2 Cu; v 9; NW 1.
Jan. 17, few Acu, 1 Cu; ⦶; v 8; WNW 7.
Jan. 18, lt hz; ⦶; v 9; NNW 7.
Jan. 20, 2:12, a.m.; ⦶; dns hz; v 4; NE 1. 0:02, p.m., 2 Ci; dns hz; v 4; NEN 1.
Jan. 22, 0:20, p.m., 3 Ci, few Cu; hz; v 7; S 2.
Jan. 24, 1:57, a.m., 2 Acu; ⦶; lt hz; v 8; NW 7. 1:19, a.m., 1 Acu; ⦶; lt hz; v 8; NW 6.
Jan. 24, 0:07, p.m., lt hz; ⦶; v 8; NWN 6.
Jan. 25, 2:22, a.m., 2 Ci: hz; v 6; SSW 5. 1:58, a.m., 1-2 Ci; v 6; SWS 5.
Jan. 31, 2:17, a.m., few Acu; v 8; SW 3.

POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. J. F. Hellweg, U.S. Navy, Superintendent U.S. Naval Observatory. Data furnished by the U.S. Naval Observatory in cooperation with Harvard and Mount Wilson Observatories. Difference in longitude is measured from the central meridian, positive west. North latitude is positive. Areas are corrected for foreshortening and are expressed in millionths of the sun's visible hemisphere. The total area for each day includes spots and groups]

Date	Eastern standard time		Heliographic			Area		Total area for each day	Observatory
			Diff. in longitude	Longitude	Latitude	Spot	Group		
1933	h.	m.	°	°	°				
Jan. 1	14	52	No spots						U.S. Naval.
Jan. 2	13	58	No spots						Do.
Jan. 3	11	12	No spots						Mount Wilson.
Jan. 4	11	18	No spots						Do.
Jan. 5	11	26	No spots						Do.
Jan. 6	11	18	No spots						Do.
Jan. 7	10	51	No spots						Do.
Jan. 8	11	43	No spots						U.S. Naval.
Jan. 9	12	0	No spots						Do.
Jan. 10	11	50	No spots						Do.
Jan. 11	—	—	No spots						Do.
Jan. 12	12	45	+4.0	147.4	+5.0		16	16	Mount Wilson.
Jan. 13	12	30	+18.0	148.4	+5.0		29	29	Do.
Jan. 14	12	50	+32.0	149.1	+4.0		42	42	Do.
Jan. 15	11	27	+45.0	149.7	+4.5		46	46	U.S. Naval.
Jan. 16	13	19	+59.0	149.5	+4.5		69	69	Do.
Jan. 17	11	52	+73.0	151.1	+4.5		69	69	Do.
Jan. 18	11	36	No spots						Do.
Jan. 19	11	35	No spots						Do.
Jan. 20	11	44	No spots						Do.
Jan. 21	12	56	No spots						Do.
Jan. 22	10	50	No spots						Mount Wilson.
Jan. 23	13	52	No spots						U.S. Naval.
Jan. 24	11	5	No spots						Do.
Jan. 25	11	30	No spots						Do.
Jan. 26	13	56	No spots						Do.
Jan. 27	11	46	No spots						Do.
Jan. 28	13	1	No spots						Do.
Jan. 29	11	20	No spots						Do.
Jan. 30	11	26	−47.0	220.2	+30.0		39	39	Do.
Jan. 31	11	21	−34.0	220.1	+30.0		39	39	Do.
Mean daily area for January								11	

PROVISIONAL SUN-SPOT RELATIVE NUMBERS FOR JANUARY 1934

(Dependent alone on observations at Zurich and its station at Arosa)

[Data furnished through the courtesy of Prof. W. Brunner, Eidgen. Sternwarte, Zurich, Switzerland]

January 1934	Relative numbers	January 1934	Relative numbers	January 1934	Relative numbers
1	0	11	0	21	0
2	0	12	*Mc* 8	22	
3		13	11	23	
4	0	14	12	24	0
5	0	15	13	25	0
6	0	16		26	0
7	0	17	11	27	0
8	0	18		28	0
9	0	19	0	29	*Ec* 8
10	0	20		50	11
				31	

Mean: 24 days = 3.1.

c = New formation of a center of activity; *E*, on the eastern part of the sun's disk; *W*, on the western part; *M*, in the central zone.

AEROLOGICAL OBSERVATIONS

[Aerological Division, L. T. Samuels, temporarily in charge]

By L. T. SAMUELS

Free-air temperatures for January, as shown in table 1, averaged above normal at all stations except Boston and Pensacola. Departures of considerable magnitude occurred at Omaha, and Pembina. Relative humidity departures for the month were of opposite sign to those for temperature except at Cleveland, Dallas, and Omaha, where the departures were positive for both of these elements.

In most cases the resultant free-air wind directions for the month did not differ appreciably from the normals (table 2). Moderate excesses in the resultant velocities were general at the northern stations but elsewhere no consistent variations from the normals occurred.

During January, the International month for 1934, 46 sounding balloons were released from the Omaha Airport Station. To date 33 of the meteorographs carried by these balloons have been returned.

TABLE 1.—*Free-air temperatures and relative humidities obtained by airplanes during January 1934*

TEMPERATURE (° C.)

Altitude (meters) m.s.l.	Boston, Mass.[1] (6 meters)		Cleveland, Ohio[2] (246 meters)		Dallas, Tex.[3] (146 meters)		Omaha, Nebr.[4] (300 meters)		Pembina, N.Dak.[5] (243 meters)		Pensacola, Fla.[6] (2 meters)		San Diego, Calif.[6] (9 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	−4.3	(7)	−1.3	(7)	5.9	(7)	−3.9	(7)	−15.9	(7)	10.2	−1.1	11.6	−0.8
500	−6.1	(7)	−1.2	(7)	7.9	(7)	−2.1	(7)	−13.2	(7)	9.6	−1.3	14.1	+2.0
1,000	−6.7	−4.1	−2.8	+3.4	8.3	+2.6	.4	+5.0	−8.8	+2.5	8.5	−1.1	13.5	+2.9
1,500	−7.8	−4.6	−3.5	+3.1	7.1	+2.1	.5	+4.6	−7.7	+3.1				
2,000	−9.7	−5.3	−4.9	+2.7	5.2	+1.8	−.5	+4.9	−8.3	+4.3	5.3	−1.4	8.8	+2.7
2,500	−11.8	−5.6	−7.0	+2.4	2.6	+1.3	−2.9	+4.7	−10.3	+4.3				
3,000	−14.0	−5.3	−8.9	+2.8	−.2	+0.9	−5.6	+4.5	−12.6	+4.5	−.4	−2.7	3.2	+1.9
4,000	−18.5	−3.5	−14.2	+2.3	−6.2	+0.4	−11.7	+3.7	−18.0	+4.9	−6.0	−2.8	−4.5	+1.4
5,000	−24.3	−4.1	−20.8	+2.6	−13.4	−0.7	−18.2	+3.3	−24.0	+4.0	−11.2	−2.8		

RELATIVE HUMIDITY (PERCENT)

Altitude (meters) m.s.l.	Boston Mean	Boston Departure	Cleveland Mean	Cleveland Departure	Dallas Mean	Dallas Departure	Omaha Mean	Omaha Departure	Pembina Mean	Pembina Departure	Pensacola Mean	Pensacola Departure	San Diego Mean	San Diego Departure
Surface	76	(7)	77	(7)	87	(7)	84	(7)	84	(7)	82	0	69	+3
500	77	(7)	75	(7)	78	(7)	82	(7)	77	(7)	78	+2	49	−10
1,000	77	+10	74	+9	71	+10	72	+6	68	+2	73	+4	36	−15
1,500	76	+14	69	+11	62	+8	67	+8	63	+3				
2,000	76	+17	67	+14	55	+6	62	+5	59	0	64	+7	28	−12
2,500	73	+18	67	+14	49	+3	62	+6	55	−3				
3,000	71	+19	64	+10	45	+3	61	+5	53	−4	58	+9	25	−6
4,000	70	+18	58	+3	35	−3	58	+5	52	−2	51	+9	24	−5
5,000	71	+23	57	−2	32	−4	56	+2	50	−7	53	+9		

[1] Airplane observations made by Massachusetts Institute of Technology; departures based on normals obtained from 264 kite observations made at Blue Hill Meteorological Observatory (1896–1903).
[2] Temperature departures based on normals determined by extrapolating latitudinally those of Royal Center, Ind., and Due West, S.C. Humidity departures based on normals of Royal Center, Ind.
[3] Temperature departures based on normals determined by interpolating latitudinally those of Groesbeck, Tex., and Broken Arrow, Okla. Humidity departures based on normals of Groesbeck, Tex.
[4] Temperature and humidity departures based on normals of Drexel, Nebr.
[5] Temperature departures based on normals determined by extrapolating latitudinally those of Ellendale, N.Dak., and Drexel, Nebr. Humidity departures based on normals of Ellendale, N.Dak.
[6] Naval air stations.
[7] Surface and 500-meter level departures omitted because of difference in time of day between airplane observations and those of kites upon which the normals are based.

Times of observations: Weather Bureau, 5 a.m.; Navy, 7 a.m.; and Massachusetts Institute of Technology, 8 a.m. (E.S.T.).

TABLE 2.—*Free-air resultant winds (meters per second) based on pilot-balloon observations made near 7 a.m. (E.S.T.) during January 1934*

[Wind from N=360°, E=90°, etc.]

Altitude (meters) m.s.l.	Albuquerque, N. Mex. (1,554 meters)		Atlanta, Ga. (309 meters)		Bismarck, N.Dak (518 meters)		Brownsville, Tex. (7 meters)		Burlington, Vt. (132 meters)		Cheyenne, Wyo. (1,873 meters)		Chicago, Ill. (192 meters)		Cleveland, Ohio (245 meters)		Dallas, Tex. (154 meters)		Havre, Mont. (762 meters)		Jacksonville, Fla. (14 meters)		Key West, Fla. (11 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°	
Surface	341	1.2	319	2.1	308	1.9	346	0.4	215	1.9	296	6.0	258	2.4	234	3.8	310	0.6	240	4.0	330	1.9	60	2.6
500			332	4.8			134	3.7	222	4.3			252	6.9	242	6.8	225	2.3			353	1.5	85	5.7
1,000			319	5.7	297	8.1	184	3.3	254	5.8			271	11.2	263	12.1	256	5.5	251	9.6	250	3.1	104	4.1
1,500			301	7.3	297	10.7	190	3.9	273	9.3			279	12.7	272	13.0	274	6.0	276	14.3	260	5.2	114	1.2
2,000	351	3.4	292	11.1	294	11.3	221	4.1	293	13.9	296	8.7	281	10.2	284	17.3	294	7.6	281	12.9	261	7.1	259	1.2
2,500	312	4.3	283	11.0	300	13.9	219	7.3	294	17.0	311	11.1	288	10.4	284	16.5	286	8.6	285	14.0	261	8.1	270	2.6
3,000	298	5.5	272	11.0	292	11.2	224	7.0	276	17.0	314	11.2	290	13.6	285	16.9	291	9.9	295	14.7	261	9.4	282	4.4
4,000	302	7.7	272	12.0			244	7.8			299	9.6					277	10.2	290	10.8			276	6.2
5,000	293	8.4									329	5.7												

Altitude (meters) m.s.l.	Los Angeles, Calif. (217 meters)		Medford, Oreg. (410 meters)		Memphis, Tenn. (83 meters)		New Orleans, La. (1 meter)		Oakland, Calif. (8 meters)		Oklahoma City, Okla. (402 meters)		Omaha, Nebr. (306 meters)		Phoenix, Ariz. (338 meters)		Salt Lake City, Utah (1,294 meters)		Sault Ste. Marie, Mich. (198 meters)		Seattle, Wash. (14 meters)		Washington, D.C. (10 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°	
Surface	350	1.0	187	0.3	145	0.5	33	1.2	83	1.6	274	1.2	306	1.1	101	1.8	162	1.8	358	0.6	175	2.2	292	1.0
500	28	1.3	213	0.2	236	4.7	63	1.8	34	4.4	254	1.9	276	3.2	85	2.8			329	7.1	197	7.6	272	5.2
1,000	26	2.3	161	1.0	263	5.2	29	1.6	22	6.9	271	4.5	283	7.4	65	2.2			312	4.9	202	6.4	276	8.3
1,500	20	3.8	246	3.0	274	8.6	268	5.4	5	6.2	283	6.1	289	9.5	65	1.8	176	2.5	298	6.7	203	3.9	290	10.1
2,000	11	5.3	269	3.5	277	10.2	276	7.3	350	7.1	292	7.5	280	10.3	43	1.1	214	1.1	286	9.9			287	10.8
2,500	11	5.6	314	5.7	289	10.2	262	9.6	350	7.0	293	8.0	277	12.8	345	1.4	296	2.9					295	10.2
3,000	357	6.2	315	8.3	290	10.5	258	11.3	346	6.8	292	9.5	281	13.6	317	3.3	298	5.7					286	9.6
4,000	359	7.1	314	11.7					330	7.0	287	12.1			321	5.6	323	10.0						
5,000	335	6.9													314	5.2	324	10.5						

RIVERS AND FLOODS

By RICHMOND T. ZOCH

[River and Flood Division, MONTROSE W. HAYES, in charge]

In the greater part of the country the rivers were low in December 1933. Exceptions were the basin of the Green River of Kentucky, where there was a minor overflow, which caused only slight losses, and the Columbia Basin of the Northwest, where severe and damaging floods occurred.

Floods in the Columbia were not unknown in December, but this one was quite unusual, both on account of its severity and the great length of time it prevailed. At Vancouver, Wash., on the Columbia River, a crest stage of 22.3 feet occurred on December 25, 1933, exceeding by 4.8 feet the highest previous record for December. The fact that this flood caused so much more damage in the basin as a whole than higher spring and early summer floods have caused is an apparent anomaly. However, spring and early summer floods are due largely to melting snow and the very high stages are confined almost wholly to the Columbia proper. The December 1933 flood was caused principally by excessive rains and the greatest damage occurred in tributary and minor streams. The following excerpts from reports of the Weather Bureau offices in Portland, Oreg., and Seattle and Yakima, Wash., are of interest, and give complete details of the floods.

Portland, Oreg.—December 1933 was one of the wettest months ever experienced in western Washington and northwestern Oregon. At Portland only one wetter month has been recorded since records were begun in 1871.

At the beginning of the month streams in this region were low. The first threat of high water was on the morning of the 6th. At that time one atmospheric depression had passed inland over southwestern Canada during the night, and another was centered in the Gulf of Alaska. Very heavy rains had fallen in the middle and lower portions of the Willamette Basin, and in all of western Washington.

The next serious threat was on the morning of the 18th, when wide-spread and heavy, warm rains were reported. Flood warnings were issued for the Santiam River at Jefferson, Oreg., and for the Cowlitz River at Kelso, Wash. The warning for the Santiam was verified but the flood stage at Kelso was not reached till later.

A critical period in the freshet was reached on the morning of the 22d. Very heavy rains had fallen during the night from Albany, Oreg., northward, and rapid rises were reported in most of the streams in this region. A stage of 24 or 25 feet was forecast for Portland, 23 or 24 feet for Vancouver, 16 feet for Oregon City, and 15 feet for Jefferson, and flood warnings were issued for Albany and Salem, Oreg. A still further rise was forecast for Kelso, Wash. Fortunately, later in the day there was a temporary lull in the heavy precipitation, and Albany did not have a flood stage, but warnings for the other places were substantially verified.

On the 23d a very rapid rise appeared in the Snake River at Riparia, Wash., causing some alarm, but it smoothed out as it proceeded, and did little more than delay the fall in the lower Columbia and in the Willamette at Portland. It came mostly from the North Fork of the Clearwater River in Idaho, as was afterward learned.

Damage done in Oregon, Washington, and Idaho, was enormous, running into millions of dollars, but the greater part of it was on streams not covered by the river and flood service of the Weather Bureau. The experience of this wet period emphasizes the necessity for a material extension of this service.

Yakima, Wash.—The Yakima and Naches Rivers began to rise noticeably on December 9, reaching, on December 12, the highest crest since 1917, and caused some slight damage to river roads, tourist camps, etc. The flood waters receded gradually from the 13th to 17th, during which period the Reclamation Bureau opened its reservoir gates to the limits of safety and discharged as much water as possible from the nearly full reservoirs. The waters began rising again on December 18 and continued fairly steadily until 2 a.m. on the 23d, when there was a maximum discharge of 53,000 second-feet at the Sunnyside diversion dam. This discharge was approximately three times that recorded on December 12.

All the Yakima and Naches River bottom lands were inundated, amounting probably to 20,000 or 25,000 acres. Much of the flat country near the town of Toppenish, Wash., was covered. All bridges, both highway and railroad, in the valley, except one, the abandoned Yakima-Selah bridge, were unusable on account of washed-out approaches. All transportation in and out of Yakima was by air lines alone for about 3 days. Between 500 and 600 families were driven out of their homes. There was some confusion on the night of December 22–23, when shallow water ran through the streets in the north and northeast portions of the city of Yakima, but there was no serious damage except to plants and structures near the river.

Total property damages amounted roughly to $1,000,000 in the Yakima and Naches Basins. Greatest losses were of roads, washed lands, houses, and stock. Very little of the commercial orchard section was touched, most of the apple trees, especially, having been planted on the deeper soils at higher elevations. The most wide-spread losses were in the vicinity of Toppenish, where hay in the stack and stored vegetables were flooded and many cattle, hogs, sheep, and chickens perished. Very unfortunate, also, were the results of the flood in the upper Naches River region. Much work had been expended for years to construct a first-class highway into this beautiful scenic and recreational region, including an eastern gateway into the Rainier National Park. Considerable portions of this highway were washed entirely away; years probably will be required to replace the highway and for the area to recover.

It was fortunate, but rather remarkable, that only two human lives were lost by drowning.

The floods were the result of a combination of circumstances, namely: A heavy snow covering on the upper drainage areas, unseasonably warm weather with melting of snow and copious rainfall. A marked temperature accumulation took place after October 1 and through December. Precipitation for December averaged about 25 inches in the upper drainage areas, an amount far above normal, and with considerable fresh snowfall.

Seattle, Wash.—Heavy and continuous rains during December 1933 wrought havoc and devastation over much of western and portions of eastern Washington. The swift water of swollen streams and rivers swept away bridges and damaged their approaches, washed out culverts, destroyed the surfaces of highways, and inundated lowlands. On the coast and Sound region, gales lashed unusually high tides, driving salt water inland and flooding coastal towns and reclaimed areas. Transportation facilities were paralyzed, and for a time Seattle, Tacoma, Yakima, Wenatchee, and other cities in Washington were isolated except for travel by boat or airplane. Communication was hampered and the water supply of several towns was cut off. The damage will undoubtedly total $9,000,000 in addition to the 14 lives that were lost in the State. This enormous toll and wide-spread damage, plus hardships endured by thousands of people forced from their homes, represents the greatest loss the State has ever suffered from a similar catastrophe.

The flood situation became of major importance on December 10, when the rivers of southwestern Washington and their tributaries overflowed their banks. In addition to the heavy local rains, mild temperature and rains at high elevations released tremendous quantities of water from the melting mountain snows. The Puyallup River broke through its dykes when it reached a flood stage much greater than ever before experienced or even anticipated. The deluge of fresh water was further impounded by extremely high tides which flooded coastal towns and some of the tide flats in the Sound region. At Tacoma, where much damage was done and a portion of the city inundated, the tide rose to 2.2 feet above the predicted high level. Farm houses were carried away by the rampant waters, fields submerged, and herds drowned. Bridges, highways, and roadbeds were the vulnerable points upon which the flood worked destruction. Certain highways were entirely impassable. Busses and trains cooperated to maintain passenger service from Seattle to Portland. Aberdeen and Hoquiam, Wash., were completely isolated and many commercial houses and buildings in these cities were damaged. It was necessary to carry mail from Tacoma to Seattle by boat. Hundreds of families in the vicinity of Centralia and Chehalis, Wash., were marooned and had to be rescued in skiffs. Two deaths were reported in this early crisis and the flood shortly claimed two more lives.

On the following day flood conditions were manifest farther northward when a dyke on the Snohomish River crumbled and floods were reported from the Skagit Valley. However, the waters in the southwest portion were receding slightly and relief work was begun. In Seattle, where the soil was oversaturated with moisture, slides menaced several homes situated on hills.

Very little relief was accomplished during the following week because of the continuous rains, and about December 20 the situation again became critical. At this time serious conditions were reported not only from southwestern Washington, but from the Olympic Peninsula, the Wenatchee and Yakima districts, and many

other sections. On the 21st a dyke gave way on the Lewis River and the waters flooded Kelso and Woodland, Wash. At Kelso the raging current broke the water main. Woodland was almost completely evacuated as water 8 feed deep covered the main section of the town. The greatest loss occurred in Cowlitz County. The devastation was extensive and according to the Red Cross 2,800 persons were compelled to leave their homes, 795 homes were flooded, and 600 head of cattle were lost. Families throughout the county were housed in schools or private homes at the expense of the Red Cross.

Railroad lines were blocked by slides and Seattle was without train service to the east. Much holiday travel was prevented. Christmas mails were delayed and crews of postmen, organized for the final rush, had only local mail to deliver on December 23. The Snohomish and Cedar Rivers cut new channels in several places. Ten homes were destroyed as the Cedar River shifted its course. Two women were buried alive in a sea of mud as a gigantic slide engulfed a farmhouse in Maple Valley near Renton, Wash., on December 24. Drownings were reported from various localities. In Seattle there were 76 slide-areas and many homes were swept down hill sides. On the 30th six homes were hurled into the Sound at Dash Point near Tacoma.

The Red Cross and local and Federal relief agencies gave prompt assistance. At the close of the month many refugees from flood areas were returning home and commencing the task of rehabilitation. Cities, counties, and the State have appropriated funds for this purpose.

The "why" of this unusual wet period is of considerable meteorological interest. The prime factor was the pronounced polar air mass which maintained its position from the interior of eastern Alaska southeastward over northwestern Canada during the greater part of the month with varying degrees of intensity, blocking the eastward movement of low pressure areas from the Gulf of Alaska and shunting them south of their normal track. During the first 4 days low pressure persisted off the southeastern Alaska and British Columbia coast. Moderate precipitation was general in western Washington as secondary depressions passed inland over British Columbia. On December 4 a storm center of considerable intensity was central over the Gulf of Alaska, moving slowly southeastward, gathering energy and increasing in magnitude as it progressed. Although an offshoot of this storm passed eastward, the center remained over the Gulf of Alaska for 3 days, causing heavy rains in the west division and snow in the mountains. On the morning of December 8 another center was charted a little south of latitude 40 and at 146 west longitude. From this vicinity several "lows" advanced northeastward to the Washington coast and passed inland, accompanied by mild weather and heavy rains. It was the warm air masses borne aloft, that caused the melting of snows that had accumulated in the Cascade Range.

During the remainder of the month the main center of low pressure was at times just off the Washington coast, or considerably to the west over the Pacific. Sometimes it would work slightly northward to be repulsed by the polar air mass previously mentioned. Even with this shifting of the "low" secondary depressions from time to time moved eastward over Washington or British Columbia, between the high-pressure system to the north and another which was in evidence at times over the southwestern United States. The arrangement of air masses was ideal for the genesis of new "lows" which were fed by a steady stream of moist tropical air from the south Pacific. These depressions originated and moved inland with great frequency causing high winds and abundant rains.

Thus, over an area where orographic influences are favorable for the formation of rain, a persistent succession of fronts made climatic history for Washington. Of 89 stations recording precipitation in western Washington during December, 10 received a measurable amount of rain on every day of the month, 13 received rain on all days but one, and 21 stations had but two days without rain. The average number of rainy days during the month for the 89 stations was 28. Moreover, the precipitation was unusually heavy during a number of periods within the month.

In January 1934 there were minor floods in the Susquehanna, Tombigbee, Elk (in Tennessee), Sulphur (in Texas), and Willamette Rivers. Slight damage was caused in the Sulphur Basin, but none in the others.

Flood stages and dates of prevalence at Weather Bureau river-gage stations in December 1933 and January 1934 have been combined in the following table:

Table of flood stages in December 1933 and January 1934

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
ATLANTIC SLOPE DRAINAGE	*Feet*			*Feet*	
Chenango: Sherburne, N.Y.	8	Jan. 1	Jan. 2	8.1	Jan. 1
Susquehanna: Bainbridge, N.Y.	11	...do...	Jan. 4	14.2	Jan. 2
EAST GULF OF MEXICO DRAINAGE					
Tombigbee: Lock No. 3, Ala.	33	Jan. 11	Jan. 12	33.8	Jan. 12
MISSISSIPPI SYSTEM					
Ohio Basin					
Green: Lock No. 4, Woodbury, Ky.	33	Dec. 19	Dec. 22	35.4	Dec. 21
Elk: Fayetteville, Tenn.	14	Jan. 7	Jan. 7	15.1	Jan. 7
Red Basin					
Sulphur:					
Ringo Crossing, Tex.	20	Jan. 4	Jan. 6	25.0	Jan. 4
Naples, Tex.	22	Jan. 10	Jan. 12	23.0	Jan. 11
PACIFIC SLOPE DRAINAGE					
Columbia Basin					
Clearwater: Kamiah, Idaho	12	Dec. 23	Dec. 23	12.3	Dec. 23
Long Tom: Monroe, Oreg.	10	Dec. 18	Dec. 27	13.7	Dec. 22
		Dec. 7	Dec. 7	11.7	Dec. 7
Santiam: Jefferson, Oreg.	10	Dec. 18	Dec. 24	15.4	Dec. 22
		Jan. 22	Jan. 24	13.2	Jan. 23
Williamette:					
Harrisburg, Oreg.	10	Jan. 24	...do...	12.2	Jan. 24
Salem, Oreg.	20	Dec. 23	Dec. 23	20.4	Dec. 23
Portland, Oreg.	18	Dec. 22	Dec. 28	23.6	Dec. 24
Cowlitz: Kelso, Wash.	23	Dec. 21	Dec. 24	27.3	Dec. 23
Columbia: Vancouver, Wash.	15	...do...	Dec. 30	22.3	Dec. 25

The following tables are statements of estimated flood losses, and savings effected by Weather Bureau flood warnings, in the year 1933. The custom of publishing this information monthly was discontinued a year ago because many floods cover parts of 2 months, and confusion resulted from efforts to segregate the amounts by months.

STATEMENT OF ESTIMATED FLOOD LOSSES DURING THE YEAR 1933

ST. LAWRENCE DRAINAGE

Maumee River in Ohio and Indiana

Prospective crops	$5,000

Sandusky River in Ohio

Tangible property totally or partially destroyed	65,000
Prospective crops	4,000
Suspension of business, including wages of employees	250
Total	74,250

ATLANTIC SLOPE DRAINAGE

Connecticut River in Connecticut

Tangible property totally or partially destroyed	6,125
Prospective crops	4,500
Livestock and other movable property	25
Suspension of business, including wages of employees	5,000

Schuylkill River in Pennsylvania

Tangible property totally or partially destroyed	1,000,000

Delaware River in New Jersey and Pennsylvania

Tangible property totally or partially destroyed	200,000

Susquehanna River in New York and Pennsylvania

Tangible property totally or partially destroyed	$4, 178, 160
Matured crops	5, 000
Livestock and other movable property	5, 000
Suspension of business, including wages of employees	158, 718

James River in Virginia

Prospective crops	2, 000
Suspension of business, including wages of employees	2, 175

Waccamaw River in South Carolina

Tangible property totally or partially destroyed	1, 800
Matured crops	500
Suspension of business, including wages of employees	6, 300

Peedee River in South Carolina

Livestock and other movable property	40
Suspension of business, including wages of employees	4, 680

Altamaha River in Georgia

Tangible property totally or partially destroyed	2, 500
Prospective crops	1, 000
Livestock and other movable property	1, 400
Suspension of business, including wages of employees	1, 000
Total	5, 585, 923

EAST GULF OF MEXICO DRAINAGE

Apalachicola River in Florida

Tangible property totally or partially destroyed	6, 200
Prospective crops	3, 000
Livestock and other movable property	1, 000
Suspension of business, including wages of employees	5, 000

Choctawhatchee River in Alabama and Florida

Tangible property totally or partially destroyed	20
Matured crops	50
Livestock and other movable property	497
Suspension of business, including wages of employees	150

Conecuh River in Alabama

Tangible property totally or partially destroyed	750
Livestock and other movable property	200
Suspension of business, including wages of employees	2, 000

Coosa River in Georgia and Alabama

Tangible property totally or partially destroyed	19, 900
Matured crops	9, 000
Livestock and other movable property	2, 600
Suspension of business, including wages of employees	5, 000

Cahaba River in Alabama

Tangible property totally or partially destroyed	50

Alabama River in Alabama

Tangible property totally or partially destroyed	9, 852
Prospective crops	6, 878
Matured crops	700
Livestock and other movable property	6, 245
Suspension of business, including wages of employees	7, 524

Tombigbee River in Alabama and Mississippi

Tangible property totally or partially destroyed	19, 450
Prospective crops	9, 250
Matured crops	3, 000
Livestock and other movable property	47, 025
Suspension of business, including wages of employees	3, 600

Pearl River in Mississippi

Tangible property totally or partially destroyed	2, 000
Prospective crops	59, 000
Matured crops	8, 000
Livestock and other movable property	4, 000
Suspension of business, including wages of employees	5, 700

Bogue Chitto River in Louisiana

Tangible property totally or partially destroyed	$50, 000
Matured crops	3, 500
Prospective crops	75, 000
Total	376, 141

MISSISSIPPI SYSTEM—UPPER MISSISSIPPI BASIN

Rock River in Illinois

Suspension of business, including wages of employees	20, 000

Cedar and Iowa Rivers in Iowa

Tangible property totally or partially destroyed	59, 500
Prospective crops	50, 000

Des Moines River in Iowa

Tangible property totally or partially destroyed	44, 000
Prospective crops	17, 700
Matured crops	200
Suspension of business, including wages of employees	1, 000

Illinois River in Illinois

Tangible property totally or partially destroyed	70, 800
Prospective crops	377, 000
Matured crops	330, 000
Livestock and other movable property	2, 000
Suspension of business, including wages of employees	12, 800

Meramec River in Missouri

Tangible property totally or partially destroyed	7, 450
Prospective crops	25, 000
Suspension of business, including wages of employees	20, 400

Mississippi River in Missouri and Illinois

Prospective crops	1, 000
Matured crops	2, 500
Suspension of business, including wages of employees	5, 000
Total	1, 046, 350

MISSISSIPPI SYSTEM—MISSOURI BASIN

Big Sioux River in Iowa, Minnesota, and South Dakota

Tangible property totally or partially destroyed	193, 435
Prospective crops	18, 000
Matured crops	116, 000
Livestock and other movable property	9, 000
Suspension of business, including wages of employees	11, 000

Smoky Hill River in Kansas

Tangible property totally or partially destroyed	28, 500
Prospective crops	15, 000
Matured crops	5, 000
Livestock and other movable property	11, 000
Suspension of business, including wages of employees	1, 000

Cherry Creek in Colorado

Tangible property totally or partially destroyed	953, 790

Grand River in Missouri

Matured crops	5, 000
Total	1, 366, 625

MISSISSIPPI SYSTEM—OHIO BASIN

Allegheny River in Pennsylvania

Tangible property totally or partially destroyed	25, 850
Suspension of business, including wages of employees	2, 000

Monongahela River in Pennsylvania

Tangible property totally or partially destroyed	150, 000
Suspension of business, including wages of employees	25, 000

Muskingum River in Ohio

Tangible property totally or partially destroyed	$480,000
Prospective crops	300
Suspension of business, including wages of employees	100

Hocking River in Ohio

Tangible property totally or partially destroyed	151,500
Prospective crops	400
Matured crops	2,200
Suspension of business, including wages of employees	800

Scioto River in Ohio

Tangible property totally or partially destroyed	404,000

Barren River in Kentucky

Prospective crops	16,600
Matured crops	1,000
Suspension of business, including wages of employees	2,500

Green River in Kentucky

Tangible property totally or partially destroyed	4,200
Prospective crops	16,500
Matured crops	4,100
Suspension of business, including wages of employees	500

West Fork of White River in Indiana

Tangible property totally or partially destroyed	115,000
Matured crops	10,550
Prospective crops	220,600
Livestock and other movable property	10,600
Suspension of business, including wages of employees	17,000

East Fork of White River in Indiana

Tangible property totally or partially destroyed	15,000
Matured crops	12,000
Prospective crops	187,300
Suspension of business, including wages of employees	7,000

White River in Indiana

Tangible property totally or partially destroyed	34,500
Matured crops	2,750
Prospective crops	72,650
Livestock and other movable property	2,200
Suspension of business, including wages of employees	6,600

Wabash River in Indiana and Illinois

Tangible property totally or partially destroyed	80,000
Matured crops	35,260
Prospective crops	1,077,850
Livestock and other movable property	11,785
Suspension of business, including wages of employees	42,406

Cumberland River in Tennessee

Tangible property totally or partially destroyed	1,000
Suspension of business, including wages of employees	1,100

Pigeon River in Tennessee

Tangible property totally or partially destroyed	350
Prospective crops	1,500
Suspension of business, including wages of employees	100

French Broad River in Tennessee

Tangible property totally or partially destroyed	100
Prospective crops	200
Suspension of business, including wages of employees	250

Elk River in Tennessee and Alabama

Tangible property totally or partially destroyed	1,500
Prospective crops	1,250
Matured crops	1,000
Livestock and other movable property	300

Tennessee River in Alabama and Tennessee

Tangible property totally or partially destroyed	8,300
Prospective crops	5,000
Matured crops	7,000
Livestock and other movable property	250
Suspension of business, including wages of employees	11,630

Ohio River from Pittsburgh, Pa., to Cairo, Ill.

Tangible property totally or partially destroyed	$1,127,070
Prospective crops	1,244,695
Matured crops	26,377
Livestock and other movable property	43,775
Suspension of business, including wages of employees	442,830
Total	6,174,178

MISSISSIPPI SYSTEM—WHITE BASIN

Black River in Missouri and Arkansas

Tangible property totally or partially destroyed	38,600
Prospective crops	21,000
Matured crops	7,000
Livestock and other movable property	16,500
Suspension of business, including wages of employees	600

White River in Missouri and Arkansas

Tangible property totally or partially destroyed	22,300
Prospective crops	121,400
Matured crops	51,000
Livestock and other movable property	30
Suspension of business, including wages of employees	23,800
Total	302,230

MISSISSIPPI SYSTEM—ARKANSAS BASIN

Verdigris River in Kansas and Oklahoma

Tangible property totally or partially destroyed	30,000
Prospective crops	28,000
Livestock and other movable property	2,500
Suspension of business, including wages of employees	2,500

Neosho River in Kansas and Oklahoma

Tangible property totally or partially destroyed	15,000
Prospective crops	4,500
Livestock and other movable property	1,000
Suspension of business, including wages of employees	1,000

North Canadian River in Oklahoma

Prospective crops	3,200

Canadian River in Oklahoma

Tangible property totally or partially destroyed	61,100
Matured crops	12,000

Arkansas River in Kansas, Oklahoma, and Arkansas

Tangible property totally or partially destroyed	80,400
Prospective crops	270,965
Matured crops	9,450
Livestock and other movable property	20,400
Suspension of business, including wages of employees	10,800
Total	552,815

MISSISSIPPI SYSTEM—RED BASIN

Sulphur River in Texas

Tangible property totally or partially destroyed	250
Prospective crops	20,000
Livestock and other movable property	1,300
Suspension of business, including wages of employees	500
Total	22,050

MISSISSIPPI SYSTEM—LOWER MISSISSIPPI BASIN

St. Francis River in Missouri and Arkansas

Tangible property totally or partially destroyed	23,838
Prospective crops	939,200
Matured crops	22,000
Livestock and other movable property	8,300
Suspension of business, including wages of employees	119,650

Tallahatchie and Yazoo Rivers in Mississippi

Tangible property totally or partially destroyed	$150,000
Prospective crops	1,430,000
Livestock and other movable property	15,000
Suspension of business, including wages of employees	185,000

Ouachita River in Arkansas and Louisiana

Tangible property totally or partially destroyed	7,000
Livestock and other movable property	1,000
Suspension of business, including wages of employees	7,750

Lower Mississippi River from Cairo, Ill., to mouth

Tangible property totally or partially destroyed	171,230
Prospective crops	3,193,800
Matured crops	39,050
Livestock and other movable property	39,640
Suspension of business, including wages of employees	614,475
Total	6,966,933

WEST GULF OF MEXICO DRAINAGE

Sabine River in Texas and Louisiana

Tangible property totally or partially destroyed	181,990
Prospective crops	390,000
Matured crops	394,500
Livestock and other movable property	109,500
Suspension of business, including wages of employees	38,800

Rio Grande River in New Mexico

Tangible property totally or partially destroyed	2,473
Prospective crops	6,320
Suspension of business, including wages of employees	337
Total	1,123,920

PACIFIC SLOPE DRAINAGE—COLUMBIA BASIN

Clark Fork in Washington

Suspension of business, including wages of employees	2,200

Clearwater River in Idaho

Tangible property totally or partially destroyed	3,000

Snake River in Idaho

Tangible property totally or partially destroyed	20

Willamette River in Oregon

Tangible property totally or partially destroyed	2,600
Prospective crops	4,100
Livestock and other movable property	525

Columbia River in Washington and Oregon

Tangible property totally or partially destroyed	5,573,825
Matured crops	121,500
Prospective crops	379,150
Livestock and other movable property	350,450
Suspension of business, including wages of employees	111,325

Minor streams in Washington where flood service is not maintained

Tangible property totally or partially destroyed	5,182,300
Total	11,730,995
Total estimated losses for the United States	35,322,410

ESTIMATED VALUE OF PROPERTY SAVED BY WARNINGS

ST. LAWRENCE DRAINAGE

Titabawassee River in Michigan	$3,500

ATLANTIC SLOPE DRAINAGE

Connecticut River in Connecticut	$89,000
Schuylkill River in Pennsylvania	60,000
Susquehanna River in Pennsylvania	3,000
James River in Virginia	173,500
Roanoke River in North Carolina	1,000
Neuse River in North Carolina	2,000
Peedee River in South Carolina	11,650
Altamaha River in Georgia	51,500

EAST GULF OF MEXICO DRAINAGE

Apalachicola River in Florida	15,000
Choctawhatchee River in Alabama	200
Coneuch River in Alabama	500
Coosa River in Georgia and Alabama	100,000
Alabama River in Alabama	29,950
Tombigbee River in Alabama and Mississippi	289,250
Pearl River in Mississippi	7,000

MISSISSIPPI SYSTEM

Upper Mississippi Basin

Cedar and Iowa Rivers in Iowa	40,000
Illinois River in Illinois	100,000
Upper Mississippi River in Illinois and Missouri	4,500

Missouri Basin

Big Sioux River in Iowa and South Dakota	24,000
Smoky Hill River in Kansas	100

Ohio Basin

Allegheny River in Pennsylvania	500,000
Monongahela River in Pennsylvania	500,000
Muskingum River in Ohio	50,000
Hocking River in Ohio	25,000
Scioto River in Ohio	25,000
Barren River in Kentucky	15,000
Green River in Kentucky	14,900
West Fork of White River in Indiana	17,500
East Fork of White River in Indiana	5,000
White River in Indiana	17,000
Wabash River in Indiana	168,000
Cumberland River in Tennessee	8,500
Elk River in Tennessee and Alabama	3,000
Tennessee River in Tennessee and Alabama	5,800
Ohio River from Pittsburgh, Pa., to Cairo, Ill	4,351,122

White Basin

Black River in Missouri and Arkansas	8,000
White River in Missouri and Arkansas	77,250

Arkansas Basin

Neosho River in Kansas and Oklahoma	2,500
Arkansas River in Kansas, Oklahoma, and Arkansas	85,100

Red Basin

Sulphur River in Texas	65,500

Lower Mississippi Basin

St. Francis River in Missouri and Arkansas	13,000
Yazoo River in Mississippi	35,000
Ouachita River in Arkansas and Louisiana	27,500
Lower Mississippi River from Cairo, Ill., to mouth	569,010

WEST GULF OF MEXICO DRAINAGE

Trinity River in Texas	7,000
Rio Grande River in New Mexico	138,702

GULF OF CALIFORNIA DRAINAGE

Colorado River in Colorado	10,000

PACIFIC SLOPE DRAINAGE

Columbia Basin

Willamette River in Oregon	200
Columbia River in Washington and Oregon	478,075
Total estimated savings for the United States	8,228,309

WEATHER OF THE ATLANTIC AND PACIFIC OCEANS

[The Marine Division, W. F. McDONALD in charge]

NORTH ATLANTIC OCEAN

By HERBERT C. HUNTER

Atmospheric pressure.—The mean pressure during January 1934 over the North Atlantic was mainly above normal, but was distinctly below normal over the northeastern portion. Reykjavik, Iceland, averaged almost a quarter inch below normal, but the lowest reading reported there (28.40 inches, on the 12th) was not remarkable for the winter season at that station. At Lisbon and Madeira the mean pressure was two tenths of an inch above normal.

The Atlantic HIGH was not well developed during the first few days, but became more conspicuous later, especially about the 7th and 20th and again in midocean and to the eastward during the last few days. This HIGH at greatest extent is illustrated on chart VIII, for January 7.

TABLE I.—*Averages, departures, and extremes of atmospheric pressure (sea level) at selected stations for the North Atlantic Ocean and its shores, January 1934*

Stations	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Julianehaab, Greenland	29.31	----------	29.96	17	28.82	20
Reykjavik, Iceland	29.22	−0.24	30.57	31	28.40	12
Lerwick, Shetland Islands	29.61	−.09	30.53	31	28.43	18
Valencia, Ireland	29.97	+.07	30.81	31	29.12	14
Lisbon, Portugal	30.36	+.21	30.55	20	30.15	30
Madeira	30.31	+.21	30.59	22	29.93	31
Horta, Azores	30.24	+.08	30.49	31	29.85	10
Belle Isle, Newfoundland	29.85	+.05	30.30	4	29.20	26
Halifax, Nova Scotia	30.01	+.03	30.64	4, 22	28.88	29
Nantucket	30.06	+.02	30.63	4	29.06	28
Hatteras	30.16	+.02	30.50	31	29.41	28
Bermuda	30.13	−.03	30.38	6, 7	29.70	29
Turks Island	30.07	+.02	30.14	7, 8	30.00	3, 29
Key West	30.10	.00	30.26	16	29.93	29
New Orleans	30.16	+.03	30.45	30	29.79	31
Cape Gracias, Nicaragua	29.94	−.01	29.98	11, 12, 27, 28	29.82	22

NOTE.—All data based on a.m. observations only, with departures compiled from best available normals related to time of observation, except Hatteras, Key West, Nantucket, and New Orleans, which are 24-hour corrected means.

Cyclones and gales.—Cyclonic storms occurred in large number and some were of notable violence. However, the first week of the month was comparatively free from gales save a few near midocean, and the final week likewise yielded few gale reports except from the vicinity of the American coast and from far-northern waters.

High pressure was well developed across the breadth of the Atlantic about the 7th, but within a few days thereafter the deepest depression of the month was noted, being most intense when central about 700 miles to west-northwest of the northern tip of Ireland. (See charts VIII and IX.)

In connection with this LOW the minimum pressure reading so far reported during the month was recorded by the American steamship *Cold Harbor*, at noon of the 11th, about latitude 58° N. and longitude 28° W. This reading, 27.80 inches, was considerably lower than any reported thus far by a shore station adjacent to North Atlantic waters.

Two days before the lowest pressure was encountered by the *Cold Harbor* the same depression had caused the first gale of hurricane force noted during 1934 in the Atlantic, the German liner *Europa*, bound from New York to the English Channel, experiencing force 12 about 8 p.m. of the 9th, when near latitude 46° N., longitude 39° W. The gale continued along the course of the steamer for almost 40 hours after the time of greatest strength.

There was no day during January, with the single exception of New Year's Day, when gale force was not encountered at some point in the North Atlantic, and for almost a fortnight after the 11th gales were experienced with special frequency along the main northern steamship routes, but for the most part to the eastward of the fifty-fifth meridian. Nevertheless, there was no storm that rated greater than a whole gale between the 14th and 19th, inclusive.

The second North Atlantic report of hurricane force was, like the first, from the *Europa*, this time bound from Cherbourg to New York. This storm was encountered during the night of the 22–23d, the lowest barometer being noted about latitude 47° N., longitude 37° W. This intense wind was connected with a LOW which passed eastward near Newfoundland during the 19th and 20th, and for a few days afterward formed a southward extension of a large LOW over the Greenland-Iceland area, but about noon of the 22d developed marked intensity near the fortieth meridian; during the remainder of that day and the 23d it advanced eastward near the chief steamer lanes, retaining great strength; but by the morning of the 24th it had decreased somewhat and traveled north-northeastward to the region between Iceland and the Faroe Islands.

Late on the 28th a vigorous storm from south-central Canada reached the Gulf of St. Lawrence, whence it turned sharply northward to southern Baffin Land by the evening of the 30th. In connection with this storm several vessels to westward of the fiftieth meridian, but all north of the latitude of Bermuda, reported fresh to whole gales on the 28th or 29th. The third and last report of hurricane violence came in connection with this storm. The American steamship *President Van Buren*, bound from the Mediterranean to Boston, experienced force 12 about 1 p.m. of the 29th, when approximately 150 miles southeast of Cape Cod.

Fog.—Fog was in general less prevalent than usual for January, and the eastern half of the Atlantic to southward of the fiftieth parallel was practically free from fog, but to northward it was sometimes reported on one or two of the last few days of the month. Over the Grand Banks fog occurred on 3 to 5 days, and on 3 to 7 days near the coast between the Gulf of St. Lawrence and Cape Hatteras, where the period of several days about the 6th was especially foggy. New York harbor was fog-bound from the 5th to 7th, inclusive. There were a very few reports of fog on scattered dates in areas adjacent to the Gulf and South Atlantic coasts.

OCEAN GALES AND STORMS, JANUARY 1934

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Direction and highest force of wind	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN			° ′	° ′				Inches					
Europa, Ger.S.S.	English Channel.	New York	45 55 N.	42 31 W.	Jan. 2	4a, 2	Jan. 2	29.86	SW	SW., 9	WNW	SW., 9	None.
Minnequa, Am.S.S.	Copenhagen	Philadelphia	54 02 N.	37 20 W.	Jan. 1	9a, 3	Jan. 3	29.39	W	W., 8	W	W., 10	Do.
American Banker, Am. S.S.	London	New York	46 42 N.	39 06 W.	Jan. 4	11p, 4	Jan. 5	29.59	SE	NNW., 9	NNW	SE., 10	SE.-W.-NNW.
Lord Kelvin, Br.S.S.	Halifax	Valencia	46 35 N.	30 35 W.	do	8a, 5	do	29.59	SE	SW., 8	NW	SW., 9	SSW.-SW.
Nishmaha, Am.S.S.	Glasgow	Corpus Christi	[1]47 58 N.	[1]20 28 W.	Jan. 5	1a, 6	Jan. 6	29.78	S	SSW., 9	WNW	SSW., 9	S.-SSW.-WNW.
Syros, Am.S.S.	Galveston	Bremen	39 15 N.	61 05 W.	Jan. 8	6p, 8	Jan. 9	29.77	SW	W., 9	NW	W., 9	SW.-NW.
Emile Francqui, Belg.S.S.	New York	Antwerp	[1]44 40 N.	[1]42 35 W.	Jan. 9	10a, 9	Jan. 11	29.10	W	W., 10	W	W., 11	WSW.-W.-NNW.
Europa, Ger.S.S.	do	English Channel.	45 42 N.	39 24 W.	do	4p, 9	do	29.07	WSW	W., 11	W	WSW. 12.	W.-WSW.
Boston City, Br.S.S.	Newport, England.	Philadelphia	49 36 N.	35 18 W.	do	10p, 9	Jan. 12	28.20	WSW	W., 9	W	NW., 11	WSW.-W.-NW.
Black Tern, Am.S.S.	Antwerp	New York	48 52 N.	31 24 W.	Jan. 8	1a, 10	Jan. 13	28.60	SSW	W. 10	WNW	W., 10	SW.-W.-NW.
Delilian, Br.S.S.	Liverpool	Savannah	48 06 N.	20 48 W.	Jan. 10	6a, 10	Jan. 11	29.00	SSW	SW., 9	W	SW., 9	S.-SW.
Scanpenn, Am.S.S.	Copenhagen	New York	55 16 N.	32 33 W.	do	2p, 10	do	28.06	SSW	WNW., 9	WNW	W., 10	SE.-SW.-WNW.
Yaka, Am.S.S.	Rotterdam	Tampa	45 50 N.	14 15 W.	do	4p, 10	do	29.36	SW	SW., 8	SW	SW., 9	SW.-WSW.
Cold Harbor, Am.S.S.	Dundee	Boston	57 41 N.	27 38 W.	do	Noon, 11	Jan. 12	27.80	SE	W., 5	W	S., 10	
Youngstown, Am.S.S.	London	Galveston	42 30 N.	14 00 W.	Jan. 11	10p, 11	do	29.68	WSW	WSW., 10	NW	WSW., 10	WSW.-SW.
Dordrecht, Du.S.S.	Dundee	Port Arthur	59 08 N.	11 44 W.	Jan. 12	11a, 12	Jan. 13	28.41	SW	SW., 6	W	W., 9	SW.-W.
Syros, Am.S.S.	Galveston	Bremen	46 05 N.	36 50 W.	Jan. 13	4a, 13	Jan. 14	29.46	WNW	WNW., 7	WNW	W., 10	None.
West Cohas, Am.S.S.	Rotterdam	New Orleans	44 26 N.	19 00 W.	do	2p, 13	do	29.68	WSW	SW., 10	W	SW., 10	SW.-WSW.
West Eldara, Am.S.S.	Antwerp	Boston	50 15 N.	10 50 W.	do	8p, 13	Jan. 15	28.76	SW	SSW., 9	NW	NW., 11	SSW.-W.
Britsum, Du.S.S.	Buenos Aires	Rotterdam	47 35 N.	6 40 W.	do	11a, 15	Jan. 16	29.49	WSW	SW., 9	NW	WNW., 10	SW.-WNW.
Bremen, Ger.S.S.	Bremerhaven	New York	47 31 N.	31 00 W.	Jan. 16	1p, 16	do	29.03	SW	SW., 10	W	SW., 10	
Do	do	do	43 40 N.	50 10 W.	Jan. 17	11p, 17	Jan. 18	29.47	WNW	SSE., 10	W	SSE., 10	
Rotterdam, Du. M.S.	Helsingborg	Baytown, Tex.	47 05 N.	13 08 W.	Jan. 18	8a, 18	Jan. 19	29.75	SW	SW., 8	WNW	W., 10	SW.-W.
Caledonia, Br.S.S.	Glasgow	Halifax	50 32 N.	38 40 W.	Jan. 20	6p, 20	Jan. 21	29.19	W	S., 11	WNW	S., 11	S.-WSW.
West Eldara, Am.S.S.	Antwerp	Boston	50 05 N.	32 40 W.	do	11p, 20	do	29.49	SSE	SSW., 11	WSW	SSW., 11	SSE.-SSW.-WSW.
Scanstates, Am.S.S.	Copenhagen	New York	57 22 N.	25 50 W.	do	10a, 21	do	29.13	SSW	SSW., 9	SW	SSW., 10	SSW.-SW.
Exporter, Am. S.S.	Lisbon	do	36 51 N.	36 34 W.	Jan. 22	5p, 22	Jan. 22	29.74	SSW	SW., 9	W	SW., 9	SSW.-W.
Granville, Pan.M.S.	Cristobal	Liverpool	44 50 N.	34 45 W.	do	9p, 22	Jan. 23	29.14	N	NW., 9	N	NW., 11	NW.-WSW.
Europa, Ger.S.S.	English Channel.	New York	47 12 N.	36 54 W.	do	11p, 22	do	28.85	NE	N., 11	NW	NW., 12	NE.-N.-NNW.
Manhattan, Am.S.S.	Hamburg	do	47 48 N.	42 43 W.	Jan. 21	Mdt., 22	do	29.22	SSW	NNW., 8	NW	N., 10	NW.-NNW.-N.
Blommersdijk, Du.S.S.	Rotterdam	do	46 00 N.	40 02 W.	Jan. 23	2a, 23	do	[2]29.22	NE	S., 4	NW	NNW., 11	NW.-S.-NE.
New York, Ger.S.S.	Cherbourg	do	46 00 N.	41 18 W.	do	Noon, 23	do	29.24	NNW	NNW., 5	NW	NNW., 11	
Bremen, Ger.S.S.	New York	Bremerhaven	44 35 N.	42 51 W.	do	do	Jan. 24	29.84	NW	NNW., 11	WNW	NNW., 11	NW.-NNW.-WNW.
Jean Jadot, Belg.S.S.	Antwerp	New York	41 07 N.	65 38 W.	do	Mdt., 23	do	29.60	SSE	SSE., 10	W	SSE., 10	SSE.-S.-W.
City of Alma, Am.S.S.	Newcastle	Panama City, Fla.	45 00 N.	20 48 W.	do	Noon, 24	do	29.76	S	SW., 9	WSW	S., 10	SW.-WSW.
Quaker City, Am.S.S.	Dundee	Boston	[1]58 39 N.	[1]9 31 W.	Jan. 26	4a, 26	Jan. 27	29.40	WNW	SW., 7	WNW	WNW., 9.	S-WNW.
Cliffwood, Am.S.S.	Copenhagen	Norfolk	53 10 N.	33 55 W.	Jan. 27	4a, 28	do	29.70	S	S., 7	S	S., 9	S.-SW.
Cities Service Kansas, Am.S.S.	Boston	Galveston	41 05 N.	69 15 W.	Jan. 29	Mdt., 28.	Jan. 30	29.18	NW	SW., 4	NW	NW., 10	SW.-NW.
Pres. Van Buren, Am.S.S.	Gibraltar	Boston	38 50 N.	67 20 W.	Jan. 27	3a, 29	Jan. 29	[2]29.06	SSW	WNW., 8.	WNW	WNW., 12	SSW.-WNW.
Exporter, Am.S.S.	Lisbon	New York	36 34 N.	62 16 W.	Jan. 29	3p, 29	Jan. 31	29.40	SSW	SW., 10	NW	SW., 10	SSW.-WNW.
NORTH PACIFIC OCEAN													
City of Vancouver, Br. S.S.	Muroran	Seattle	[1]44 33 N.	[1]153 42 E.	Dec. 31	1p., Jan. 1.	Jan. 1	[2]28.30	ESE	W., 7	WSW	SW., 9	
Kuretake Maru, Jap. S.S.	Miike	do	45 19 N.	161 45 E.	do	6a, 2	Jan. 2	[2]28.67	S	W., 7	WSW	S., 9	WSW.-W.
Pres. Cleveland, Am. S.S.	Seattle	Yokohama	44 35 N.	158 00 E.	Jan. 1	10p., 1	Jan. 3	28.63	SW	WSW., 11.	W	WNW., 11.	SW.-WSW--W
Pres. Jefferson, Am.S.S.	Yokohama	Victoria	45 35 N.	163 00 E.	do	3a, 3	do	[2]29.12	WNW	W., 8	WSW	WNW., 9.	None.
Saparoea, Du.M.S.	Cebu	Vancouver	40 54 N.	160 30 E.	Jan. 5	11p., 5	Jan. 5	29.26	WSW	WNW., 5.	W	SW., 10	SW.-WNW.-NW.
Pres. Jefferson, Am.S.S.	Yokohama	Victoria	50 02 N.	144 21 W.	Jan. 7	8a., 7	Jan. 7	[2]28.64	E	S., 9	S	S., 10	SE.-S.
Niagara, Br.S.S.	Victoria	Honolulu	34 19 N.	145 43 W.	Jan. 6	do	do	29.84	S	SW., 6	SW	SSW., 9	SW.
W. S. Rheem, Am.S.S.	Los Angeles	Balboa	15 22 N.	95 50 W.	Jan. 7	4p., 7	Jan. 8	29.55	NE	ENE., 6	NNE	NNE., 8	E.-NE.
Pres. Jackson, Am.S.S.	Victoria	Yokohama	51 00 N.	135 15 W.	do	Mdt., 7.	do	29.47	SSE	SSE., 9	S	SSE., 9	SSE.-S.
Kuretake Maru, Jap.S.S.	Miike	Seattle	48 59 N.	142 50 W.	Jan. 10	7p., 10	Jan. 10	[2]29.16	ESE	SE., 8	S	SE., 8	ESE.-SE.-S.
City of Vancouver, Br. S.S.	Muroran	do	48 36 N.	150 30 W.	Jan. 11	4p., 10	Jan. 11	[2]28.65	NW	SSW., 5	WNW	NW., 9	E.-S.
Batoe, Du.S.S.	Java	Los Angeles	34 05 N.	173 58 E.	Jan. 10	4a., 11	do	[2]29.54	S	W., 7	W	S., 9	SW.-W.
San Diego Maru, Jap. S.S.	Monterey	Yokohama	30 53 N.	144 42 E.	Jan. 11	8a., 11	do	29.30	W	WSW., 6	NW	NW., 8	SSE.-WSW.-NW.
Empress of Japan, Br.S.S.	Honolulu	do	30 17 N.	153 47 E.	do	5p., 11	Jan. 12	29.36	SSE	SW., 8	W	W., 9	S.-SW.-W.
Kuretake Maru, Jap.S.S.	Miike	Seattle	40 02 N.	134 10 W.	Jan. 12	4a., 13	Jan. 13	[2]29.08	W	S., 8	W	S., 8	S.-W.
Bellingham, Am.S.S.	Seattle	Yokohama	39 30 N.	147 42 E.	do	3a., 14	Jan. 15	29.38	NW	WNW., 8.	NW	WNW., 10	None.
Makiki, Am.S.S.	Port Townsend.	Hawaii	46 00 N.	131 00 W.	Jan. 15	9a., 15	Jan. 16	29.52	ESE	SE., 9	WSW	SE., 9	ESE.-SE.-SW.
Pres. Grant, Am.S.S.	Yokohama	Victoria	40 46 N.	152 50 E.	do	4p., 15	Jan. 15	29.42	NW	NW., 8	NW	NW., 9	NW.
Pres. Jackson, Am.S.S.	Victoria	Yokohama	44 40 N.	152 23 E.	Jan. 16	4a., 16	Jan. 16	29.35	NW	NW., 8	WNW	WNW., 9.	
Empress of Asia, Br.S.S.	Yokohama	Vancouver	49 36 N.	174 00 W.	do	11p., 16	Jan. 17	29.03	E	ENE., 9	E	ENE., 9	ENE.-ESE.
Shoyo Maru, Jap.S.S.	Estero Bay	Yokohama	31 58 N.	149 41 E.	Jan. 17	Noon, 17	Jan. 18	[2]29.33	SW	SW., 10	WNW	SW., 10	SW.-WNW.
Ibukisan Maru, Jap.S.S.	Yokohama	Los Angeles	37 54 N.	152 04 E.	do	2p., 17	Jan. 19	[2]28.81	N	NE., 7	NW	NW., 8	E.-N.
Stanley Dollar, Am.S.S.	Philippine Islands.	San Francisco	39 30 N.	173 15 E.	do	Noon, 19	do	29.05	SSE	WSW., 10	WSW	WSW., 11	None.
Steel Inventor, Am.S.S.	Vancouver	Hilo	43 30 N.	133 30 W.	Jan. 18	5a., 19	do	29.56	SW	W., 10	W	W., 11	SW.-W.
Pres. Grant, Am.S.S.	Yokohama	Victoria	49 02 N.	172 24 W.	do	2a., 19	do	29.14	ESE	ENE., 10	NE	ENE., 10	
Ogura Maru, Jap.M.S.	San Luis	Yokohama	33 31 N.	169 06 E.	Jan. 19	Noon, 18	do	29.33	WNW	SSW., 7	NW	WNW., 9.	SSW.-WSW.
Golden Horn, Am.S.S.	Otaru	San Francisco	43 58 N.	157 54 E.	Jan. 18	8a., 18	Jan. 20	28.99	N	N., 9	WNW	NW., 10	N.-NNW.
San Diego Maru, Jap. S.S.	Yokohama	do	37 00 N.	152 48 E.	Jan. 20	10a, 20	do	29.10	S	SW, 3	SSE	SSE., 8	SW.-S.
Patrick Henry, Am.S.S.	Cebu	Los Angeles	28 52 N.	154 05 E.	Jan. 21	4p, 21	Jan. 22	29.47	W	W, 8	W	W, 8	None.
Asama Maru, Jap.M.S.	Yokohama	Honolulu	33 25 N.	168 10 E.	Jan. 20	Mdt. 21	do	29.30	SSE	SW., 8	SW	S, 9	Do.
Ogura Maru, Jap.M.S.	San Luis	Yokohama	33 25 N.	160 07 E.	Jan. 21	4a, 22	Jan. 24	29.10	SSW	W., 8	NW	W., 10	Do.
Golden Horn, Am.S.S.	Otaru	San Francisco	44 38 N.	172 58 E.	Jan. 22	2p., 22	Jan. 22	28.74	E	W., 10	W	E., 10	E-W.
Pres. Jefferson, Am.S.S.	Victoria	Yokohama	52 30 N.	148 18 W.	Jan. 23	Noon, 23	Jan. 23	[2]29.26	S	SSW., 10	SW	SSW., 10	S-SSW-SW.
Stanley Dollar, Am.S.S.	Philippine Islands.	San Francisco	43 12 N.	161 20 W.	Jan. 22	1p., 23	Jan. 25	29.52	SE	SSE., 8	S	SSE., 9	SW-SSE-S.
Manoeran, Du.M.S.	Cebu	Los Angeles	29 41 N.	174 47 W.	Jan. 26	4p., 26	Jan. 27	[2]29.67	W	W., 9	WNW	W., 9	None.
Pres. Cleveland, Am.S.S.	Yokohama	Seattle	35 24 N.	141 00 E.	Jan. 28	9p, 27	Jan. 28	30.17	NNW	NW., 7	N	NW., 8	Do.
Bonneville, Nor.M.S.	Manila	Los Angeles	34 49 N.	154 47 E.	do	Noon, 28.	Jan. 29	29.76	NW	NW., 9	N	NW., 9	
Manoeran, Du.M.S.	Cebu	do	31 41 N.	159 22 W.	do	6a., 29	do	[2]29.62	S	SSW., 9	W	W., 10	SSW.-W.
Patrick Henry, Am.S.S.	do	do	34 10 N.	169 12 W.	Jan. 29	2a., 29	do	29.00	W	NW., 10	W	NW, 10	WSW.-NW.-W.
San Diego Maru, Jap.S.S.	Yokohama	San Francisco	44 11 N.	148 49 W.	do	8p., 29	Jan. 30	29.00	SE	S., 8	SW	S., 8	S.

[1] Position approximate.

[2] Barometer uncorrected.

NORTH PACIFIC OCEAN, JANUARY 1934

By WILLIS E. HURD

Atmospheric pressure.—Barometer readings throughout northern waters of the North Pacific Ocean during January 1934 changed greatly from those of the preceding month. While in December the Aleutian LOW was practically nonexistent, in January it was strongly centered east of the Peninsula of Alaska, with average pressure at Kodiak, 29.37 inches, which was 0.22 inch below the normal. At this station the highest pressure of the month was 29.96, on the 23d.

From northern Japan eastward a succession of LOWS, many of them deep and extensive in area, crossed northern and middle Pacific waters. In middle longitudes cyclonic conditions extended farther south than usual, as they did in December, with the result that Midway Island continued to have abnormally low pressure. The average barometer over the Phillippine Islands was also much lower than usual for the month.

The lowest pressure reading at sea during January was 28 inches, reported by the American S.S. *Golden Sun*, near 52° N., 151° W., on the 30th.

The North Pacific anticyclone lay centered off the California coast. While variable in area, its average center was not penetrated by cyclones at any time in the month. Another anticyclone covered the seas between Japan and China.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, North Pacific Ocean, January 1934, at selected stations*

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Point Barrow	30.08	0.00	30.58	14, 15	29.62	21
Dutch Harbor	29.51	−.07	30.44	11	28.44	27
St. Paul	29.68	+.05	30.54	11	28.78	28
Kodiak	29.37	−.22	29.96	23	28.84	28
Juneau	29.62	−.26	30.31	5	29.03	16
Tatoosh Island	30.10	+.12	30.55	6	29.41	19
San Francisco	30.22	+.11	30.45	8	29.69	1
Mazatlan	29.98	+.03	30.14	9	29.92	3, 18, 20, 24
Honolulu	30.03	+.03	30.16	8	29.90	26
Midway Island	29.93	−.10	30.14	13	29.50	28
Guam	29.92	+.02	29.98	14, 25, 26, 30	29.80	7
Manila	29.87	−.11	29.98	25	29.82	12, 13, 31
Naha	30.13	+.05	30.34	25	29.86	31
Chichishima	30.03	+.02	30.30	28	29.66	4
Nemuro	29.80	----------	30.40	28	29.16	12

NOTE.—Data based on 1 daily observation only, except those for Tatoosh Island, San Francisco, and Honolulu, which are based on 2 observations. Departures are computed from best available normals related to time of observation.

Cyclones and gales.—Stormy weather prevailed over portions of the North Pacific on practically every day in the month, but was most concentrated over individual areas between 160° E. longitude and the coast of Japan, and latitudes 30° and 45° N. In this region there were at least 16 days having gales of force 8 and over, with the maximum force 11, occurring on the 1st and 2d southeast of the Kuril Islands. Barometer readings below 29 inches occurred during the prevalence of the heavier gales. The minima reported were 28.30 inches (uncorrected), on the 1st, and 28.67, on the 2d, both at or near 45° N., 154°–162° E. Near this region (in 44° N., 168° E.) the Japanese M.S. *Nankai Maru* reported a corrected minimum reading of 28.22, without gale winds, on the 29th.

East of Honshu, in the 5-degree square 35°–40° N., 145°–150° E., gales of force 8–10 were reported on 7 days, 4 of the days, 12th to 15th, being successive. Toward midocean the frequency of gales rapidly diminished until, between latitude 35° N., and the central Aleutians, few high winds were reported.

During several of the last days of the month the neighborhood of Midway Island was under the influence of a strong low centered far to the northward. Gale winds during the period occurred only in the southern quadrants of this cyclone, and from the 26th to 29th the Dutch motorship *Manoeran* encountered severe gales from near Midway eastward to 32° N., 155° W.

There were approximately 10 days in January with gales over the eastern third of the northern and central steamer routes. These were well distributed throughout the month. The maximum force was 11 from the west on the 19th, near 43°30′ N., 133°30′ W.

At the time of the low pressure reading of 28 inches reported by the *Golden Sun* in the cyclone of the 30th, south of Kodiak, the wind was only of force 8, from southeast. The strongest wind reported in this storm, despite its great depth, was of force 10, near 52° N., 151° W., on the 31st.

Tropical gales.—No low-latitude gales seem to have occurred in the Tropics of the Far East. In the Gulf of Tehuantepec a norther of force 8 occurred on the 7th, and on the 16th a moderate north gale was experienced in the Bay of Panama.

Fog.—The great percentage of the North Pacific fog occurred along the American coast. Fog was reported on 5 days between the mouth of the Columbia River and Eureka; on 13 days between Eureka and Point Arguello; and on 17 days thence southward to Cape San Lucas. Its appearance was sporadic elsewhere over the ocean.

SUMMARY OF SEA-SURFACE TEMPERATURE DATA FOR 1933

By GILES SLOCUM

Table 1 shows the mean monthly sea-surface temperatures for each month of 1933 in the Caribbean Sea and the Straits of Florida. For comparison, the 13-year means (1920 to 1932, inclusive) have been included as "normal." The data for December 1933 are based on incomplete returns and may be somewhat revised in future publications of data involving 1933 sea-surface temperatures.

CARIBBEAN SEA

The Caribbean Sea was warmer than normal during the first 10 months of 1933. This was the fourth successive year with temperatures of the surface water in that area almost continuously above the 13-year average. No record high or low average temperatures occurred for any month, though June 1933 was the second warmest June in the 14 years record from 1920 to 1933. The temperatures from January to May were only slightly above normal. Those of the summer months were unusually high.

STRAITS OF FLORIDA

The Straits of Florida were much warmer than normal during the first 5 months. The temperatures for April and May 1933 were new record highs. The summer temperatures were lower than normal. As a whole, 1933 was a year of warmer than normal temperature in the Straits of Florida surface waters.

TABLE 1.—*Mean sea-surface temperatures (° F.), for each month of 1933*

Year and month	Caribbean Sea		Straits of Florida	
	Mean	13-year normal	Mean	13-year normal
1933	° F.	° F.	° F.	° F.
January	79.4	79.1	75.6	74.9
February	78.6	78.5	75.9	74.7
March	79.1	78.8	75.2	74.9
April	80.0	79.4	78.2	76.7
May	81.3	80.7	80.0	78.8
June	82.6	81.5	81.4	81.5
July	82.5	81.8	83.0	83.2
August	83.0	82.4	83.7	84.0
September	83.5	82.9	83.3	83.5
October	82.8	82.6	81.8	81.5
November	81.6	81.7	79.0	78.7
December [1]	80.2	80.4	76.6	76.6
Year	81.2	80.8	79.5	79.2

[1] Preliminary figures from incomplete data.

CLIMATOLOGICAL TABLES

DESCRIPTION OF TABLES AND CHARTS

Table 1 gives the data ordinarily needed for climatological studies for about 179 Weather Bureau stations making simultaneous observations at 8 a.m. and 8 p.m. daily, seventy-fifth meridian time, and for about 23 others making only one observation. The altitudes of the instruments above ground are also given.

Beginning with January 1, 1932, all wind movements and velocities published herein are corrected to true values by applying to the anemometer readings corrections determined by actual tests in wind tunnels and elsewhere.

Table 2 gives, for about 37 stations of the Canadian Meteorological Service, the means of pressure and temperature, total precipitation, depth of snowfall, and the respective departures from normal values except in the case of snowfall. The sea-level pressures have been computed according to the method described by Prof. F. H. Bigelow in the REVIEW of January 1902, **30:** 13–16.

CHART I.—*Temperature departures.*—This chart presents the departures of the monthly mean surface temperatures from the monthly normals. The shaded portions of the chart indicate areas of positive departures and unshaded portions indicate areas of negative departures. Generalized lines connect places having approximately equal departures of like sign. This chart of monthly surface temperature departures in the United States was first published in the MONTHLY WEATHER REVIEW for July 1909, but smaller charts appear in W. B. Bulletin U for 1873 to June 1909, inclusive.

CHART II.—*Tracks of centers* of ANTICYCLONES; and

CHART III.—*Tracks of centers* of CYCLONES. The roman numerals show the chronological order of the centers. The figures within the circles show the days of the month, the location indicated being that at 8 a.m., seventy-fifth meridian time. Within each circle is also an entry of the last three figures of (chart II) the highest barometric reading, or (chart III) the lowest reading reported at or near the center at that time, in both cases as reduced to sea level and standard gravity. The intermediate 8 p.m. locations are indicated by dots. The inset map of chart II shows the departure of monthly mean pressure from normal and the inset of chart III shows the change in mean pressure from the preceding month.

The use of a new base map for charts II and III began with the January 1930 issue.

CHART IV.—*Percentage of clear sky between sunrise and sunset.*—The average cloudiness at each regular Weather Bureau station is determined by numerous personal observations between sunrise and sunset. The difference between the observed cloudiness and 100 is assumed to represent the percentage of clear sky, and the values thus obtained are the basis of this chart. The chart does not relate to the night hours.

CHART V.—*Total precipitation.*—The scales of shading with appropriate lines show the distribution of the monthly precipitation according to reports from both regular and cooperative observers. The inset on this chart shows the departure of the monthly totals from the corresponding normals, as indicated by the reports from the regular stations.

CHART VI.—*Isobars at sea level, and isotherms at surface; prevailing winds.*—The pressures have been reduced to sea level and standard gravity by the method described by Prof. Frank H. Bigelow in the REVIEW for January, 1902, **30:** 13–16. The pressures have also been reduced to the mean of the 24 hours by the application of a suitable correction to the mean of 8 a.m. and 8 p.m. readings at stations taking two observations daily, and to the 8 a.m. or the 8 p.m. observation, respectively, at stations taking but a single observation.

The diurnal corrections so applied, except for stations established since 1901, will be found in the Annual Report of the Chief of the Weather Bureau, 1900–1901, volume 2, table 27, pages 140–164.

The sea-level temperatures are now omitted and average surface temperatures substituted. The isotherms cannot be drawn in such detail as might be desired, for data from only the regular Weather Bureau Stations are used.

The prevailing wind directions are determined from hourly observations at almost all the stations. A few stations determine their prevailing directions from the daily or twice-daily observations only.

CHART VII.—*Total snowfall.*—This is based on the reports from regular and cooperative observers and shows the depth in inches of the snowfall during the month. In general, the depth is shown by lines connecting places of equal snowfall, but in special cases figures also are given. This chart is published only when the snowfall is sufficiently extensive to justify its preparation. The inset of this chart, when included, shows the depth of snow on the ground at or near the end of the month.

CHARTS VIII, IX, etc.—*North Atlantic Weather maps of particular days.*

CLIMATOLOGICAL TABLES

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, January 1934

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	50.2	+3.9	2 stations	79	[1] 1	2 stations	5	30	3.71	−1.22	Robertsdale	6.95	Tallassee	1.47
Arizona	45.1	+1.0	Benson	84	25	Fort Valley	1	8	.33	−.79	Naco	1.00	5 stations	.00
Arkansas	44.5	+3.1	Highland	78	28	2 stations	2	30	2.85	−1.40	Crossett	5.50	Mammoth Spring	1.39
California	46.9	+2.1	Palm Springs	85	31	Bridgeport	−10	[1] 8	2.08	−2.73	Crescent City (near)	12.23	3 stations	.00
Colorado	30.3	+6.4	Two Buttes	76	31	Hermit (near)	−26	12	.22	−.53	Columbine	1.67	12 stations	.00
Florida	61.6	+2.4	5 stations	87	[1] 26	Monticello	18	31	1.49	−1.27	Cottage Hill	8.45	Belle Glade	.14
Georgia	49.8	+2.6	2 stations	82	[1] 4	Blairsville	−10	30	2.61	−1.55	Rome	6.44	Fargo	.92
Idaho	32.3	+8.2	Grand View	65	23	Obsidian	−16	12	2.24	+.15	Roland	15.95	May	.00
Illinois	33.9	+7.4	Sparta	69	27	3 stations	−10	[1] 29	1.18	−1.11	Greenville	2.40	Keithsburg	.49
Indiana	34.4	+5.3	2 stations	67	24	Whiting	−7	29	1.38	−1.72	Frankfort	2.47	Whiting	.41
Iowa	26.9	+8.3	Keokuk	67	24	3 stations	−14	29	.83	−.24	Iowa Falls	2.15	Olin	.19
Kansas	36.3	+6.5	Sedan	74	24	Centralia	−7	30	.43	−.23	Norwich	2.32	2 stations	.00
Kentucky	40.4	+4.6	Quicksand	72	24	Mount Sterling	−3	30	1.85	−2.49	Manchester	3.56	Quicksand	.67
Louisiana	54.0	+2.4	Lake Charles	82	1	6 stations	20	[1] 9	6.86	+1.99	De Ridder	10.69	Pearl River	3.18
Maryland-Delaware	37.1	+4.2	4 stations	70	25	3 stations	−6	[1] 29	2.49	−.74	Grantsville, Md	5.66	Keedysville, Md	1.09
Michigan	26.6	+6.6	St. Joseph	62	25	St. Ignace	−24	29	1.23	−.65	Deer Park	3.30	Owasso	.23
Minnesota	16.1	+6.3	Pipestone	54	27	Big Falls	−46	29	.55	−.18	Pigeon River Bridge	1.20	Tracy	.05
Mississippi	50.5	+3.2	Forest	80	1	4 stations	9	30	3.37	−1.65	Hattiesburg	7.48	Jackson	1.24
Missouri	36.1	+5.2	3 stations	71	[1] 24	Harrisonville	−6	30	1.24	−.98	Dexter	2.73	Conception	.37
Montana	29.4	+9.6	Browning	66	20	Browning	−25	24	.72	−.16	Heron	7.33	2 stations	T
Nebraska	31.5	+9.6	4 stations	70	27	Nenzel	−13	25	.29	−.26	Hay Springs	1.21	4 stations	.00
Nevada	37.3	+7.9	Las Vegas	73	[1] 22	San Jacinto	0	25	.47	−.71	Marlette Lake	2.15	2 stations	.00
New England	22.8	+.1	4 stations	57	25	Bloomfield, Vt	−44	31	3.31	−.07	Lincoln, Maine	5.92	Bethlehem, N.H	1.47
New Jersey	33.6	+2.7	Belleplain	64	28	Charlottesburg	−1	31	2.55	−1.02	Woodcliff Lake	4.07	Belleplain	.92
New Mexico	34.7	+1.0	2 stations	80	[1] 1	Therma (near)	−31	8	.21	−.35	Levy	1.55	27 stations	.00
New York	25.2	+2.0	Flushing	58	28	McKeever	−33	30	2.80	−.10	Hoffmeister	5.47	Elmira	.94
North Carolina	44.5	+2.9	2 stations	80	7	Mount Mitchell	−18	30	2.17	−1.47	Highlands	6.38	Lumberton	.71
North Dakota	15.8	+9.6	do	54	[1] 24	Edmore	−36	29	.20	−.27	3 stations	.80	Wishek	.00
Ohio	33.3	+4.8	3 stations	64	[1] 21	Bangorville	−5	30	1.55	−1.48	Phalanx	2.48	Versailles	.73
Oklahoma	42.4	+4.1	Hollis	79	24	Watts	8	29	1.75	+.29	Eufaula	3.70	Hollis	.00
Oregon	40.0	+8.1	Fremont	82	31	Sand Creek	1	11	3.81	−.01	Tillamook	17.11	Umatilla	.10
Pennsylvania	32.2	+4.3	Irwin	67	1	Gouldsboro	−19	29	2.54	−.71	Elk Lick	5.27	Mount Lebanon	.97
South Carolina	47.3	+1.4	Ferguson	82	6	Caesars Head	−2	30	1.88	−1.68	Caesars Head	4.57	Effingham	.34
South Dakota	25.7	+9.5	3 stations	67	[1] 23	White Lake	−22	3	.25	−.30	Lead	1.32	4 stations	.00
Tennessee	42.8	+3.7	McKenzie	78	24	Elkmont	−4	30	2.91	−1.78	Kingston	4.98	Kenton	1.35
Texas	50.6	+2.4	Fort Stockton	89	24	Muleshoe	7	8	3.72	+1.90	Bronson	12.45	7 stations	.00
Utah	31.2	+6.0	2 stations	67	[1] 29	Soldier Summit	−18	12	.79	−.41	Silver Lake	4.02	Hanksville	.00
Virginia	40.5	+3.9	do	77	[1] 27	Burkes Garden	−7	30	1.62	−1.51	Pennington Gap	4.00	Woodstock	.55
Washington	38.1	+6.1	North Head	66	28	Stockdill's Ranch	−17	15	7.13	+2.21	Wynooche Oxbow	35.06	Sunnyside	.28
West Virginia	36.7	+4.2	Bancroft	71	7	Bayard	−15	29	2.75	−.87	Davis	6.98	Union	.54
Wisconsin	23.3	+8.0	Wisconsin Dells	57	24	Danbury	−28	29	.85	−.33	Marshfield	1.82	Viroqua	.30
Wyoming	26.9	+6.8	Wheatland	68	23	Moran	−25	12	.52	−.27	Bechler River	4.56	Cody	.00
Alaska														
Hawaii	70.2	+1.9	2 stations	88	[1] 18	Kanalohuluhulu	39	16	6.13	−3.12	Puhonua	35.36	2 stations	.00
Puerto Rico	72.5	−.2	Lares	92		Guineo Reservoir	39	30	4.27	+.69	Toa Alta	10.02	Potala	.00

[1] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau Stations, January 1934*

[Compiled by Annie E. Small]

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	Pct.	In.	In.		Miles								0-10	In.	In.
New England							25.9	+1.4										77	3.30	−0.2										6.4		
Eastport	76	67	85	29.95	30.04	+0.04	19.4	−1.0	44	23	28	−13	31	11	51	17	15	87	2.94	−1.0	15	9,427	nw.	51	e.	14	9	5	17	6.5	14.4	9.0
Greenville, Maine	1,070	6		28.81	30.04		10.8		41	6	20	−28	31	0	41				2.89		14	5,412	nw.	26		24	11	2	18		27.9	
Portland, Maine	103	82	117	29.94	30.07	+.02	23.6	+1.2	48	6	32	−11	31	15	41	20	15	73	4.40	+.4	15	6,287	n.	35	s.	23	12	9	10	5.2	12.7	5.5
Concord	289	70	79				21.7	+.1	48	6	31	−16	31	12	39				2.66		12		nw.				7	13	11		16.1	
Burlington	403	11	48	29.61	30.08	+.03	16.4	−2.4	41	6	25	−17	31	8	43				3.04	+1.3	12	8,641	s.	41	s.	22	7	6	18	7.2	28.0	4.5
Northfield	876	12	60		30.09	+.04	16.2	+1.0	46	6	28	−30	31	5	49			88	2.52	+.2	13	5,561	n.	22	s.	31	5	10	16	7.2	22.7	17.8
Boston	125	336	360	29.93	30.07	+.02	29.6	+1.7	56	25	37	−2	29	22	38	26	19	69	2.67	−.9	9	11,349	w.	54	w.	29	6	13	12	6.6	.8	.0
Nantucket	12	14	90	30.05	30.06	+.02	32.8	+1.5	50	1	39	7	30	26	33	30	26	79	3.30	−.5	11	11,469	w.	38	ne.	2	8	10	13	6.6	.8	.0
Block Island	26	11	46	30.05	30.08	+.01	33.2	+2.2	49	28	39	8	30	28	34	31	26	77	3.06	−.7	9	13,472	w.	45	nw.	24	7	12	12	6.1	T	.0
Providence	160	215	251	29.90	30.08	+.02	30.6	+3.4	57	25	38	0	29	23	34	27	21	70	3.80	+.1	8	9,264	nw.	49	nw.	29	9	12	10	5.4	.1	.0
Hartford	159	70	104		30.11	+.04	29.9	+4.4	56	25	37	2	29	23	28				3.74	−.2	9	6,241	nw.				7	11	13		1.1	T
New Haven	106	74	153	29.99	30.11	+.03	31.6	+3.4	53	25	39	5	30	25	28	28	22	71	3.52	−.5	7	6,399	n.	27	w.	29	3	15	13	6.6	T	T
Middle Atlantic States							36.6	+4.4										72	2.23	−1.0										6.6		
Albany	97	107	115	30.00	30.12	+.05	25.2	+2.1	50	25	33	−6	29	17	30	23	18	76	2.36	.0	11	5,855	s.	24	n.	1	5	4	22	7.5	5.5	T
Binghamton	871	60	68	29.12	30.08	.00	28.0	+3.9	54	1	35	−4	29	21	36				1.53	−.9	12	5,253	nw.	27	nw.	24	3	3	25	8.8	2.3	.4
New York	314	415	454	29.76	30.11	+.01	34.4	+3.5	57	28	42	5	30	27	26	30	23	67	3.35	−.3	9	10,309	nw.	56	nw.	29	8	7	16	6.5	.2	.0
Bellefonte	1,050	5	42	28.96	30.10		29.1		49	1	36	0	30	22	33	26	23	81	1.44		10		w.				6	4	21	7.4	~~1.5~~	~~T~~
Harrisburg	374	94	104	29.71	30.13	+.03	33.8	+4.8	54	25	40	6	30	27	27	29	23	67	2.78	−.3	10	5,987	w.	30	nw.	29	6	9	16	6.6	.2	.0
Philadelphia	114	123	367	30.02	30.15	+.04	37.8	+5.2	59	25	44	10	30	32	24	33	25	64	2.91	−.4	9	9,455	w.	34	w.	29	8	8	15	6.0	T	.0
Reading	323	283	304	29.76	30.13		34.1	+4.7	58	28	41	6	30	28	30	31	25	69	2.64	−.9	11	8,958	nw.	46	nw.	29	9	8	14	6.1	.2	.0
Scranton	805	72	104	29.21	30.11	+.02	30.1	+3.5	47	1	36	0	29	24	28	28	23	75	1.58	−1.4	11	5,608	sw.	32	nw.	29	4	7	20	7.6	2.1	.0
Atlantic City	52	37	172	30.08	30.14	+.03	38.3	+5.8	56	25	45	8	30	32	30	34	29	73	1.46	−2.0	10	11,877	w.	50	nw.	29	7	10	14	6.6	T	.0
Sandy Hook	22	10	57	30.09	30.11		34.2		56	28	40	7	30	29	29	32	28	80	2.84	−1.1	8	11,192	w.	44	nw.	29	7	8	16	6.4	T	.0
Trenton	190	159	183	29.92	30.13		34.2	+3.7	59	28	41	7	30	27	30	30	25	72	3.37	+.1	10	7,223	nw.	24	nw.	17	6	10	15	6.5	.2	.0
Baltimore	123	100	215	30.01	30.14	+.02	39.0	+5.2	70	25	46	8	30	32	34	34	28	70	2.53	−1.0	10	7,965	sw.	39	nw.	28	9	9	13	5.9	T	.0
Washington	112	62	85	30.02	30.15	+.02	39.0	+5.6	69	25	46	8	30	32	31	33	26	66	1.97	−1.6	10	5,520	nw.	32	nw.	29	9	9	13	6.3	T	.0
Cape Henry	18	8	54	30.12	30.14		44.8	+4.6	74	7	52	12	31	38	37	40	36	77	2.19	−1.0	10	9,298	sw.	48	nw.	29	9	9	13	5.9	.0	.0
Lynchburg	681	153	188	29.41	30.18	+.05	41.2	+3.7	71	28	52	4	30	30	48				1.92	−1.5	10		sw.				9	12	10		T	.0
Norfolk	91	170	205	30.06	30.17	+.04	45.6	+5.0	72	7	54	10	30	38	44	40	35	73	1.88	−1.2	10	9,681	ne.	45	w.	28	12	5	14	5.8	.0	.0
Richmond	144	11	52	30.01	30.17	+.03	42.4	+4.5	70	28	52	5	30	33	38	36	31	72	1.63	−1.6	8	6,535	nw.	34	n.	29	11	9	11	5.7	T	.0
Wytheville	2,304	49	55	27.70	30.16	+.04	37.4	+4.4	64	7	46	−3	30	29	34	32	27	73	.90	−2.2	9	6,448	w.	35	nw.	29	13	7	11	5.4	.6	.0
South Atlantic States							49.7	+3.6										74	1.76	−1.7										5.3		
Asheville	2,253	89	104	27.77	30.21	+.06	40.6	+5.2	69	28	50	0	30	31	33	34	28	70	1.66	−1.4	9	7,095	nw.	34	nw.	29	10	10	11	5.6	T	.0
Charlotte	779	244	267	29.33	30.18	+.03	45.0	+3.8	70	27	52	8	30	38	36	39	32	67	1.18	−2.8	9	8,559	sw.	35	w.	28	13	8	10	5.1	.0	.0
Greensboro	886	6	56	29.20	30.18		41.4		69	27	51	4	30	32	40	35	31	76	1.59		7	6,217	ne.	32	nw.	29	12	7	12	5.5	.0	.0
Hatteras	11	5	50	30.14	30.15	+.01	50.2	+3.1	69	7	56	17	30	44	36	46	44	82	3.90	−.5	14	9,766	n.	37	nw.	29	11	8	12	5.4	.0	.0
Raleigh	376	103	146	29.76	30.18	+.05	46.2	+5.1	74	7	55	8	30	38	48	40	33	68	1.77	−1.9	6	6,709	w.	37	nw.	29	11	6	14	5.7	.0	.0
Wilmington	72	73	106	30.10	30.18	+.04	50.5	+4.0	74	7	60	11	30	41	44	44	39	74	1.15	−2.1	12	6,607	n.	30	sw.	1	12	9	10	4.8	.0	.0
Charleston	48	11	92	30.13	30.18	+.03	52.6	+2.7	73	5	60	18	30	45	31	47	43	77	1.80	−1.2	9	7,585	n.	25	sw.	1	10	8	13	5.5	.0	.0
Columbia, S.C.	351	41	57	29.80	30.19	+.04	49.1	+3.1	74	7	58	14	30	40	39	43	37	71	1.10	−2.3	7	5,617	ne.	27	sw.	7	12	7	12	5.1	.0	.0
Augusta	182	62	77	29.98	30.18	+.02	49.7	+2.7	73	7	60	15	30	40	37	43	38	73	1.83	−2.1	11	4,548	nw.	22	w.	28	12	7	12	5.3	.0	.0
Savannah	65	73	152	30.11	30.18	+.03	54.9	+3.5	77	7	64	23	30	46	33	48	44	78	2.16	−.6	7	7,809	w.	32	w.	28	11	7	13	5.1	.0	.0
Jacksonville	43	86	110	30.12	30.17	+.02	58.0	+2.6	79	7	67	28	30	49	34	52	48	78	1.08	−1.7	7	5,905	ne.	25	sw.	28	9	9	13	5.7	.0	.0
Florida Peninsula							68.1	+2.6										79	1.73	−0.7										4.5		
Key West	22	10	64	30.08	30.10	.00	71.4	+1.9	80	7	76	57	11	66	17	65	63	82	1.10	−.9	6	7,022	ne.	24	nw.	29	16	10	5	3.9	.0	.0
Miami	25	124	168	30.11	30.14	+.01	69.4	+2.9	81	27	75	45	31	64	26	63	59	75	2.94	+.4	4	7,120	se.	19	n.	30	9	13	9	5.5	.0	.0
Tampa	35	88	197	30.12	30.16	+.04	63.4	+3.0	81	6	72	34	30	54	33	56	53	79	1.16	−1.5	4	7,974	n.	23	nw.	29	14	13	4	4.1	.0	.0
Titusville	44	5	25	30.10	30.16		61.3		82	7	72	33	30	51	32				1.20		7		nw.				8	11	12		.0	.0
East Gulf States							51.8	+3.7										76	3.52	−1.1										5.8		
Atlanta	1,173	190	198	28.92	30.18	+.03	45.2	+2.6	68	28	53	7	30	38	30	41	38	79	2.72	−2.2	9	8,718	e.	38	nw.	29	12	6	13	5.4	.0	.0
Macon	370	76	84	29.79	30.20	+.04	49.8	+3.0	73	6	60	14	30	40	37	43	37	72	2.57	−1.6	9	5,380	nw.	24	nw.	29	15	2	14	5.3	.0	.0
Thomasville	273	49	103	29.88	30.19	+.03	54.8	+3.8	77	6	64	22	30	46	32	48	45	78	1.39	−2.7	7		e.				8	5	18		.0	.0
Apalachicola	35	11	19	30.12	30.16		56.3		75	27	64	27	30	49	27	52			3.03	−.6	12		ne.				9	12	10		.0	.0
Pensacola	56	149	185	30.10	30.17	+.03	56.5	+4.0	74	1	63	25	30	50	33	52	50	85	4.11	+.1	8	9,727	ne.	40	se.	24	11	4	16	5.7	.0	.0
Anniston	741	9	57				48.0	+5.8	70	28	58	9	30	38	48				4.47		9		nw.				11	7	13		.0	.0
Birmingham	700	11	48	29.40	30.19	+.03	48.6	+3.5	71	28	57	10	30	40	33	43	37	72	3.98	−1.5	12	5,793	e.	26	se.	4	11	7	13	5.6	.0	.0
Mobile	57	125	161	30.10	30.16	+.01	55.2	+3.7	76	1	63	24	30	47	34	50	45	76	4.31	−.5	11	6,924	n.	32	nw.	29	10	5	16	5.7	.0	.0
Montgomery	218	92	105	29.94	30.20	+.04	51.6	+3.4	75	1	59	18	30	44	30	45	40	70	1.86	−3.3	13	5,587	e.	22	n.	29	9	5	17	6.2	.0	.0
Meridian	375	67	92	29.77	30.18	+.02	50.8	+3.8	74	28	60	16	30	42	35	45	40	76	3.16	−2.2	14	4,789	e.	22	ne.	28	11	8	12	5.6	.0	.0
Vicksburg	247	65	73	29.90	30.17	+.02	51.4	+3.2	71	27	60	20	30	43	27	46	41	76	5.54	+.2	11	5,789	se.	21	se.	3	8	8	15	6.2	T	.0
New Orleans	53	76	84	30.10	30.16	+.03	57.8	+3.6	78	1	64	29	30	51	25	52	49	78	6.00	+1.7	10	5,343	e.	25	e.	31	9	6	16	6.1	.0	.0
West Gulf States							52.1	+3.8										79	5.32	+2.4										5.8		
Shreveport	249	92	227	29.88	30.16	+.02	50.7	+3.7	74	28	58	21	30	43	27	46	43	81	5.91	+2.0	11	7,174	ne.	31	ne.	29	8	10	13	6.1	.0	.0
Bentonville	1,303	11	44	28.72	30.12	−.02	40.0	+5.9	66	24	49	8	30	30	32				1.99		9	5,072	sw.	22	ne.	28	8	8	15		2.0	.0
Fort Smith	457	79	94	29.65	30.15	+.01	43.0	+3.5	70	24	51	15	30	35	32	38	33	73	2.11	−.4	11	5,928	e.	24	e.	3	9	13	9	5.6	T	.0
Little Rock	357	94	102	29.78	30.18	+.03	44.8	+3.4	70	24	53	14	30	36	36	40	35	75	2.63	−2.1	11	5,846	s.	24	n.	28	11	5	15	6.0	T	.0
Austin	605	136	148	29.49	30.12		53.0	+3.5	81	22	62	29	8	44	33	48	44	77	9.13	+7.1	11	5,719	n.	25	nw.	7	11	5	15	5.7	.0	.0
Brownsville	57	88	96	30.00	30.06		64.0	+4.2	81	28	71	42	31	57	24	59	57	84	2.37	+.9	13	7,122	se.	28	nw.	6	6	14	11	6.4	.0	.0
Corpus Christi	20	11	78	30.10	30.12	+.02	60.4	+4.4	77	1	67	38	9	54	26	56	54	84	4.78	+3.2	12	7,087	ne.	26	nw.	11	8	9	14	6.3	.0	.0
Dallas	512	220	227	29.58	30.14		48.0		73	24	56	22	30	40	28	44	39	77	1.28	−1.1	8	8,555	n.	38	w.	7	15	3	13	5.0	.0	.0
Fort Worth	670	106	114	29.42	30.15	+.03	48.9	+3.5	75	24	58	22	30	40	35				1.86	−.2	10	6,253	nw.	26	nw.	7	14	5	12	4.8	.0	.0
Galveston	54	106	114	30.07	30.13	.00	57.6	+3.8	76	1	63	36	30	52	23	54	52	86	8.42	+5.0	13	7,538	e.	29	e.	31	11	5	15	5.6	.0	.0
Houston	138	292	314	29.99	30.14		56.1	+3.4	78	22	63	31	8	49	26				9.94	+6.2	10	8,473	se.	29	ne.	11	12	4	15	5.9	.0	.0
Palestine	510	64	72	29.60	30.15	+.03	51.2	+3.0	75	24	59	26	8	43	29	46	43	78	5.35	+1.9	9	5,786	ne.	25	n.	28	11	7	13	5.5	.0	.0
Port Arthur	34	58	66	30.09	30.13		55.8		80	1	63	30	30	49	28				8.50	+4.8	11	6,017	e.	30	nw.	3	8	9	14	6.4	.0	.0
San Antonio	693	242	301	29.37	30.10	.00	55.2	+2.9	75	22	64	32	8	46	28	50	44	73	4.88	+3.4	16	8,219	n.	38	e.	24	9	9	13	5.9	.0	.0

TABLE 1.—*Climatological data for Weather Bureau Station, January 1934*—Continued

District and station	Elevation of instruments			Pressure			Temperature of the air									Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation			Wind					Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Barometer above sea level	Thermometer above ground	Anemometer above ground	Station, reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷ 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range				Total	Departure from normal	Days with 0.01, or more	Total movement	Prevailing direction	Maximum velocity: Miles per hour	Maximum velocity: Direction	Maximum velocity: Date						
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F		°F	°F.		°F	°F.	°F.	°F.	N	In.	In.		Miles								0-10	In.	In.
Ohio Valley and Tennessee							**38.5**	**+4.5**										**74**	**2.25**	**−1.6**										**6.5**		
Chattanooga	762	190	215	29.36	30.20	+0.04	45.2	+4.0	70	28	53	8	30	38	39	40	36	74	4.20	−1.1	10	5,933	ne.	32	nw.	28	10	12	9	5.1	0.0	0.0
Knoxville	995	79	97	29.10	30.19	+.04	43.2	+4.4	68	28	51	5	30	35	40	38	33	73	3.96	−.7	10	5,114	sw.	27	sw.	28	13	6	12	5.5	T	.0
Memphis	399	78	86	29.74	30.18	+.02	45.2	+4.3	69	24	53	11	30	38	42	41	37	76	2.62	−2.2	10	5,858	sw.	30	n.	28	9	7	15	6.1	T	.0
Nashville	546	168	191	29.61	30.21	+.05	42.4	+3.8	65	27	50	6	30	34	46	38	34	75	2.99	−1.8	9	6,906	w.	41	nw.	28	9	5	17	6.5	T	.0
Lexington	989	193	230																													
Louisville	525	188	234	29.59	30.19	+.05	38.4	+4.0	64	24	46	2	30	31	44	34	28	69	1.01	−3.0	7	8,059	s.	38	nw	28	10	5	16	6.0	T	.0
Evansville	431	76	116	29.70	30.18	+.04	38.9	+5.4	62	24	46	4	30	32	45	35	29	72	1.09	−2.6	11	7,237	s.	30	nw.	28	5	11	15	6.7	.3	.2
Indianapolis	822	194	230	29.24	30.15	+.03	34.0	+5.6	62	24	42	−1	29	26	51	30	25	71	1.25	−1.7	12	8,916	s.	40	nw.	28	8	4	19	7.0	1.0	T
Terre Haute	575	96	129	29.52	30.15		35.4		62	24	43	1	29	28	47	31	27	75	2.07	−.6	9	7,740	s.	31	s.	31	7	5	19	6.9	1.3	.3
Cincinnati	627	11	51	29.46	30.17	+.05	36.0	+5.7	62	24	44	0	30	28	45	32	27	74	1.61	−1.9	10	6,718	sw.	30	nw.	28	11	2	18	6.5	.3	.0
Columbus	822	216	230	29.24	30.14	+.03	34.0	+5.4	57	21	41	1	30	27	42	31	26	74	1.16	−1.9	11	9,549	sw.	45	nw.	28	10	4	17	6.5	2.1	T
Elkins	1,947	59	67	28.05	30.19	+.07	34.4	+4.0	64	7	44	−4	30	25	44	31	27	79	3.37	−.4	17	5,941	w.	32	nw.	28	4	9	18	7.3	2.6	T
Parkersburg	637	77	82	29.51	30.19	+.07	36.4	+3.9	60	1	45	−2	30	28	42	32	27	73	1.91	−1.7	13	5,476	sw.	35	nw.	28	8	3	20	7.1	.2	T
Pittsburgh	842	353	410	29.21	30.14	+.03	33.8	+3.1	58	1	41	−1	30	27	40	30	26	74	2.02	−1.0	13	8,723	w.	41	nw.	28	4	5	22	7.7	2.1	.2
Lower Lake Region							**28.4**	**+4.0**										**77**	**1.74**	**−0.8**										**8.2**		
Buffalo	767	243	280	29.20	30.06	−.01	27.5	+2.9	48	25	34	−5	29	21	36	25	23	83	1.64	−1.7	21	14,458	sw.	49	sw.	31	1	4	26	8.9	7.2	1.8
Canton	448	10	61	29.56	30.06		16.4	+.1	46	23	26	−19	20	7	48				2.36	−.1	17	7,656	e.	30	w.	25	7	5	19	7.0	14.8	2.1
Ithaca	836	74	100	29.14	30.08		27.6	+3.3	53	1	34	−3	29	21	37	26	21	76	1.18	−1.0	9	8,840	nw.	35	se.	23	1	3	27	9.3	1.7	T
Oswego	335	71	85	29.70	30.08	+0.1	25.0	+1.1	47	25	31	−7	29	19	38	24	21	83	2.23	−.7	19	8,949	se.	32	nw.	23	0	2	29	9.6	10.8	1.7
Rochester	523	86	102	29.49	30.09	+0.2	27.6	+3.0	50	25	34	−4	29	21	39	26	21	75	1.94	−1.0	21	5,871	sw.	25	w.	23	0	5	26	9.3	8.5	2.0
Syracuse	596	65	79	29.42	30.09	+0.2	27.3	+4.3	53	1	34	−6	29	20	39				2.18	−.8	20	6,491	w.	28	nw.	28	1	1	29	9.4	11.6	4.4
Erie	714	130	166	29.29	30.09	+0.1	30.6	+3.8	55	1	37	3	29	24	37	28	24	78	2.04	−.7	17	11,571	sw.	38	nw.	29	2	6	23	8.4	4.0	.0
Cleveland	762	267	337	29.24	30.09	.00	33.1	+6.6	58	1	40	1	29	26	44	29	24	71	1.58	−.9	15	11,697	w.	60	w.	28	5	5	21	7.5	3.9	.6
Sandusky	629	5	67	29.40	30.10	+.01	32.4	+6.1	58	21	40	2	30	25	43				1.19	−1.1	15	8,365	sw.	39	nw.	28	7	4	20	7.2	1.6	T
Toledo	628	79	87	29.40	30.10	+.01	31.8	+6.0	57	21	39	1	29	25	43	28	24	76	1.42	−.7	13	8,318	w.	33	nw.	28	10	4	17	6.5	2.6	T
Fort Wayne	857	69	84	29.16	30.12		32.0	+5.1	56	24	39	−2	29	25	43	28	25	79	1.52	−.8	14	8,487	sw.	35	nw.	28	9	3	19	6.6	1.9	.5
Detroit	626	5	78	29.38	30.09	+.01	30.0	+5.6	51	1	37	1	30	23	42	27	23	76	1.65	−.4	17	9,513	sw.	36	nw.	28	2	6	23	8.2	6.0	.5
Upper Lake Region							**25.5**	**+7.6**										**82**	**1.38**	**−0.4**										**7.9**		
Alpena	609	13	89	29.35	30.04	.00	25.4	+6.3	43	25	32	−7	29	19	40	23	20	84	1.00	−.9	16	9,309	nw.	37	nw.	28	1	8	22	8.7	9.4	2.6
Escanaba	612	54	60	29.34	30.03	−.02	23.9	+8.5	40	24	30	−11	29	18	45	22	19	84	.98	−.5	11	7,515	s.	30	nw.	28	5	3	23	7.9	9.3	8.0
Grand Rapids	707	70	244	29.28	30.07	+.01	31.0	+6.5	57	21	37	0	29	25	42	28	23	75	1.40	−1.0	13	10,084	sw.	38	sw.	31	2	9	20	8.0	1.4	.7
Lansing	878	6	88	29.09	30.06		29.2	+6.8	54	21	36	−1	29	23	42	27	25	89	1.05	−.8	13	8,760	w.	32	w.	28	1	9	21	8.2	3.0	1.0
Ludington	637	5	54																													
Marquette	734	77	111	29.17	30.00	−.04	23.3	+7.0	44	21	29	−9	29	17	36	22	20	87	3.00	+.7	22	7,738	s.	35	sw.	31	2	3	26	8.6	27.4	12.0
Sault Sainte Marie	614	11	52	29.31	30.04	+.01	19.2	+5.9	40	22	26	−19	29	12	50	18	16	88	2.54	+.6	24	7,212	se.	38	nw.	23	4	5	22	7.8	21.8	14.2
Chicago	673	7	131	29.35	30.10	.00	32.3	+8.6	55	21	39	−7	29	26	47	29	24	74	.84	−1.1	9	8,971	sw.	36	nw.	28	8	5	18	6.6	.3	.0
Green Bay	617	109	141	29.35	30.04	−.02	25.6	+9.9	49	21	32	−13	29	19	50	23	19	76	.92	−.6	9	8,758	sw.	37	nw.	28	5	4	22	7.7	6.3	T
Milwaukee	681	97	221	29.31	30.07	−.01	29.9	+9.3	56	21	36	−10	29	23	49	27	22	75	1.00	−.8	7	10,803	w.	41	nw.	28	5	4	22	7.6	.8	
Duluth	1,133	5	47	28.75	30.03	−.06	15.4	+7.5	39	27	24	−30	29	7	42	15	13	90	1.03	+.1	12	9,974	nw.	47	nw.	31	5	6	20	7.5	9.2	1.
North Dakota							**15.5**	**+10.6**										**87**	**0.31**	**−0.2**										**6.1**		
Moorhead, Minn.	940	50	58	29.02	30.09	−.05	13.8	+10.0	40	31	24	−23	29	4	47	13	11	91	.44	−.2	10	7,491	s.	30	n.	28	5	9	17	7.0	1.5	3.8
Bismarck	1,674	8	57	28.22	30.08	−.05	19.8	+12.0	49	30	31	−11	1	9	38	18	15	82	.08	−.4	3	6,612	nw.	34	nw.	31	7	15	9	5.8	.3	.0
Devils Lake	1,478	11	44	28.41	30.07	−.05	11.6	+9.8	40	23	22	−28	29	1	37	11	9	92	.55	+.1	11	7,543	sw.	35	nw.	31	8	6	17	6.4	5.4	4.0
Grand Forks	833	12	67				10.6		38	27	22	−29	29	−1	49	10			.25		8		nw.	46	nw.	31	6	11	14		1.3	7.7
Williston	1,878	41	48	28.02	30.08	−.03	16.8	+10.4	41	23	27	−13	28	6	41	16	13	83	.17	−.4	5	6,109	w.	35	nw.	31	8	13	10	5.3	1.8	5.6
Upper Mississippi Valley							**30.1**	**+8.4**										**78**	**0.99**	**−0.6**										**6.7**		
Minneapolis	918	102	208	29.03	30.06		21.2	+8.5	47	27	29	−18	29	13	44	19	16	81	.68	−.2	8	8,478	nw.	38	nw.	28	4	9	18	7.4	6.1	T
La Crosse	714	11	48	29.27	30.08	−.03	24.9	+8.8	50	24	33	−13	29	17	49	22	19	81	.86	−.2	10	4,776	s.	25	nw.	28	5	4	22	7.9	4.8	.0
Madison	974	70	78	28.98	30.08	−.02	26.6	+9.9	51	24	34	−14	29	19	50	24	21	83	.70	−.7	8	7,318	nw.	32	nw.	28	5	8	18	7.1	3.0	T
Charles City	1,015	10	51	28.98	30.11	−.03	23.6	+9.9	49	27	32	−11	29	15	48	21	18	84	.61	−.4	6	5,989	nw.	26	nw.	28	8	5	18	6.8	2.4	.0
Davenport	606	118	143	29.44	30.13	+.01	30.8	+9.0	58	24	38	−5	29	24	48	28	24	78	.77	−.6	6	7,874	sw.	35	nw.	28	8	6	17	6.6	1.7	.0
Des Moines	861	5	99	29.18	30.13	−.01	28.4	+8.3	59	27	37	−1	29	20	49	26	22	80	1.22	+.2	5	7,274	nw.	38	nw.	28	7	7	17	6.7	8.0	.0
Dubuque	700	81	96	29.32	30.10	−.02	28.4	+9.3	53	24	36	−8	29	21	46	25	22	78	.90	−.4	6	5,846	nw.	31	nw.	28	7	6	18	7.1	1.8	.0
Keokuk	614	64	78	29.45	30.15	+.01	33.0	+8.1	67	24	41	−1	30	25	47	29	24	72	.81	−.8	4	6,590	sw.	30	nw.	28	8	6	17	6.6	.4	.0
Cairo	358	87	93	29.78	30.18	+.02	40.9	+6.0	67	27	48	7	30	33	46	37	32	74	1.28	−2.5	7	6,970	s.	29	nw.	28	9	6	16	6.2	T	.0
Peoria	609	11	45	29.46	30.14	+.02	31.7	+8.6	60	24	39	−4	29	24	45	29	25	79	1.05	−.7	8	6,250	sw.	29	nw.	28	12	5	14	5.7	.8	.0
Springfield, Ill.	636	5	191	29.44	30.14	+.01	34.0	+7.5	62	24	41	0	29	27	42	30	27	78	1.33	−.8	10	9,205	s.	41	nw.	28	8	7	16	6.4	.2	.0
St. Louis	568	265	303	29.53	30.15	+.01	37.8	+7.0	65	24	46	4	29	30	46	33	27	68	1.72	−.6	5	9,179	s.	34	sw.	24	11	5	15	6.1	1.4	.0
Missouri Valley							**32.5**	**+8.4**										**75**	**0.54**	**−0.5**										**5.6**		
Columbia, Mo.	784	6	84	29.29	30.15	+.02	35.6	+6.4	70	24	44	3	30	27	41				.93	−1.0	6	6,695	sw.	30	nw.	28	12	7	12	5.1	.4	.0
Kansas City	750	32	45	29.32	30.15	.00	35.4	+7.2	70	27	44	5	30	26	42	31	27	74	.49	−.7	5	7,346	sw.	37	n.	28	11	8	12	5.6	.6	.0
St. Joseph	967	11	49	29.07	30.14		34.0		67	27	43	3	30	25	43	30	25	74	.40	−.6	4	6,613	sw.	30	nw.	28	15	4	12	5.2	.7	.0
Springfield, Mo.	1,324	98	104	28.70	30.14	.00	37.8	+4.3	67	24	46	2	30	29	39	33	29	77	1.42	−.9	6	7,389	s.	26	nw.	28	11	7	13	5.3	5.4	.0
Iola	984	11	50	29.07	30.15	+.01	38.4	+8.6	70	24	50	5	30	27	49				.98	−.3	5		s.				10	8	13		1.2	.0
Topeka	987	92	107				35.1	+7.5	69	24	45	3	30	25	46				.29	−.6	4	6,950	s.	30	nw.	28	15	3	13	5.3	1.1	.0
Lincoln	1,189	11	81	28.82	30.14	−.01	31.6	+8.8	68	27	42	1	29	22	44	27	22	71	.25	−.4	5	7,638	s.	34	nw.	31	12	8	11	5.5	2.1	.0
Omaha	1,105	115	122	28.91	30.14	−.01	30.0	+8.1	64	27	39	1	1	21	46	27	23	77	.53	−.2	5	6,988	nw.	39	nw.	31	7	9	15	6.3	5.1	.0
Valentine	2,598	47	54	27.32	30.13	+.01	30.5	+11.6	64	23	44	−6	25	16	48	24	19	69	.14	−.3	6	7,055	w.	30	sw.	23	8	12	11	5.3	1.3	.0
Sioux City	1,135	94	164	28.85	30.12	−.03	27.3	+9.5	63	27	36	−5	1	18	49	24	20	77	.50	−.2	5	7,481	nw.	32	nw.	28	6	10	15	6.9	5.0	.0
Huron	1,306	59	74	28.66	30.12	−.04	23.6	+12.3	59	27	34	−10	1	13	53	21	17	79	.06	−.5	3	7,117	n.	28	n.	28	11	8	12	5.6	.5	.0
Northern Slope							**31.0**	**+11.7**										**69**	**0.29**	**−0.5**										**5.8**		
Billings	3,140	5					34.1		62	27	46	2	2	22	39				.11		3		nw.				9	9	13		.7	
Havre	2,505	11	67	27.36	30.07	−.03	27.7	+14.8	51	26	38	−9	24	17	55	25	21	74	.22	−.5	5	9,011	sw.	31	sw.	14	7	14	10	5.8	3.1	.0
Helena	4,124	89	113	25.84	30.13	−.02	33.4	+13.2	53	27	41	1	24	26	32	29	23	64	.24	−.6	4	6,557	w.	38	w.	27	2	16	13	6.6	1.8	.0
Kalispell	2,973	48	56	27.03	30.16	+.04	33.4	+13.0	56	27	39	13	15	28	24	32	29	83	.88	−.7	13	4,005	nw.	23	w.	5	5	8	18	7.3	1.1	.0
Miles City	2,371	48	55	27.51	30.15	+.03	27.6	+13.1	52	26	38	0	1	18	40	25	21	80	.12	−.5	4	4,248	s.	26	nw.	5	11	9	11	5.5	.2	.0
Rapid City	3,259	50	58	26.61	30.13	+.03	33.6	+11.6	63	30	46	3	2	22	39	28	21	66	.19	−.3	3	6,243	w.	33	n.	6	5	18	8	5.5	.8	.0
Cheyenne	6,094	50	71	24.01	30.12	+.07	34.0	+8.5	60	27	45	11	7	23	40	26	18	56	.29	−.1	7	10,058	nw.	38	w.	14	8	13	10	5.4	3.3	.0
Lander	5,372	60	68	24.69	30.19	+.07	29.6	+11.3	56	30	43	4	7	16	40	24	18	67	.01	−.6	1	3,538	sw.	38	sw.	23	14	14	3	4.3	.2	.0
Sheridan	3,790	10	47	26.12	30.14		31.4		63	23	43	6	7	19	38	26	21	72	.32	−.5	6	3,882	nw.	33	nw.	21	5	15	11	6.1	2.9	.0
Yellowstone Park	6,241	11	48	23.96	30.28	+.14	26.2	+8.6	42	28	34	1	7	19	27	23	19	74	.61	−1.0	10	7,024	sw.	31	sw.	23	3	12	16	7.4	9.2	3.6
North Platte	2,821	11	51	27.11	30.13	+.01	33.8	+10.9	64	27	47	10	25	20	45	27	21	71	.05	−.3	3	5,827	w.	27	nw.	12	15	9	7	4.5	.1	.0

TABLE 1.—*Climatological data for Weather Bureau Stations, January 1934*—Continued

District and station	Elevation of instruments			Pressure			Temperature of the air									Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation			Wind					Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Barometer above sea level	Thermometer above ground	Anemometer above ground	Station, reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷ 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range				Total	Departure from normal	Days with 0.01, or more	Total movement	Prevailing direction	Maximum velocity: Miles per hour	Maximum velocity: Direction	Maximum velocity: Date						
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F		°F	°F.		°F	°F.	°F.	°F.	N	In.	In.		Miles								0-10	In.	In.
Middle Slope							37.9	+7.4										44	0.58	0.0										4.0		
Denver	5,292	106	113	24.75	30.09	+0.04	40.0	+10.2	69	27	51	15	7	29	40	30	16	40	0.01	-0.4	1	6,004	s.	32	n.	6	15	8	8	4.5	T	0.0
Pueblo	4,685	80	86	25.33	30.10	+.05	39.2	+9.3	69	27	54	12	8	24	48	30	17	46	T	-.3	0	5,233	n.	30	nw.	11	17	13	1	3.1	T	.0
Concordia	1,392	50	58	28.65	30.17	+.03	34.0	+7.6	68	27	44	6	30	24	40	29	23	68	.43	-.2	4	6,407	n.	27	n.	28	17	3	11	4.6	0.8	.0
Dodge City	2,509	10	86	27.48	30.16	+.05	36.7	+7.7	67	27	50	15	8	24	41	30	23	64	.29	-.1	2	8,588	n.	31	n.	28	22	6	3	2.4	2.6	.0
Wichita	1,358	85	93	28.67	30.14	+.01	36.5	+5.2	68	27	46	11	30	27	42	32	27	71	.72	-.1	4	7,871	n.	32	sw.	24	14	6	11	4.6	.9	.0
Oklahoma City	1,214	10	47	28.83	30.15	+.04	40.8	+4.4	72	24	50	15	30	31	32	36	31	74	2.06	+.9	4	7,320	s.	28	n.	28	13	8	10	4.6	1.0	.0
Southern Slope							45.8	+3.0										60	0.28	-0.4										3.5		
Abilene	1,738	10	52	28.30	30.14	+.05	47.5	+3.3	75	24	58	24	8	36	40	40	33	66	.34	-.6	5	6,404	s.	27	nw.	6	20	3	8	3.7	.0	.0
Amarillo	3,676	10	49	26.32	30.12	+.06	41.0	+5.7	72	24	54	18	4	28	39	31	19	49	.09	-.4	3	6,967	w.	27	nw.	6	22	6	3	2.5	.8	.0
Big Spring	2,537	5	62	27.47	30.15	-----	45.6	-----	77	24	59	21	8	32	44	37	30	66	.31	-----	4	-----	s.	-----	-----	-----	16	8	7	3.8	T	.0
Del Rio	944	64	71	29.09	30.10	+.04	53.6	+1.3	78	1	64	26	9	43	37	47	41	71	.67	+.1	8	6,020	nw.	27	nw.	3	14	8	9	4.8	.0	.0
Roswell	3,566	75	85	26.46	30.14	+.10	41.1	+1.9	73	24	57	15	9	25	45	32	20	48	.04	-.5	1	5,135	n.	29	n.	6	21	7	3	2.6	T	.0
Southern Plateau							44.6	+3.9										49	0.32	-0.3										1.5		
El Paso	3,778	152	175	26.27	30.12	+.11	45.4	+.4	72	24	59	19	8	32	39	35	20	39	.01	-.4	1	6,047	nw.	32	w.	2	25	4	2	1.5	T	.0
Albuquerque	4,972	51	66	25.13	30.16	-----	35.4	-----	60	28	51	9	8	20	40	27	18	57	.06	-----	1	4,797	n.	29	nw.	6	24	6	1	2.1	.1	.0
Santa Fe	7,013	38	53	23.27	30.16	+.12	32.6	+3.8	54	28	44	6	8	22	30	26	19	59	.63	.0	4	4,621	n.	21	n.	6	24	6	1	1.9	7.2	.0
Flagstaff	6,907	10	59	23.39	30.10	+.05	32.1	+5.4	55	23	47	6	8	18	42	26	-----	67	.59	-----	5	5,729	n.	29	ne.	7	19	11	1	-----	2.2	T
Phoenix	1,108	10	107	28.92	30.09	+.06	54.5	+3.3	76	27	69	34	7	40	38	42	26	38	.40	-.4	1	3,955	e.	20	e.	4	25	4	2	1.3	.0	.0
Yuma	141	9	54	29.95	30.10	+.05	57.5	+3.1	78	23	72	35	12	44	35	45	28	35	.03	-.4	2	4,850	n.	23	n.	4	27	3	1	.8	.0	.0
Independence	3,957	6	27	26.14	30.24	+.17	45.4	+7.2	70	31	59	24	11	32	37	35	-----	-----	.51	-.4	1	-----	nw.	-----	-----	-----	22	5	4	-----	.0	.0
Middle Plateau							35.6	+7.4										66	0.64	-0.4										4.2		
Reno	4,532	74	81	25.65	30.28	+.15	39.6	+7.1	64	30	52	20	9	27	37	34	27	61	.45	-1.1	3	3,748	sw.	30	sw.	19	19	11	1	2.8	T	.0
Tonopah	6,090	12	20	-----	-----	-----	36.8	-----	55	30	45	19	25	29	25	30	22	57	.18	-----	1	-----	w.	-----	-----	-----	-----	-----	-----	-----	-----	-----
Winnemucca	4,344	18	56	25.82	30.31	+.15	36.5	+7.9	58	30	50	12	9	23	36	31	26	70	.64	-.4	6	5,155	sw.	27	sw.	23	15	8	8	4.2	1.0	.0
Modena	5,473	10	46	24.74	30.22	+.12	32.2	+5.5	58	30	45	8	9	19	42	27	21	69	.23	-.6	2	6,286	e.	28	s.	24	13	15	3	3.9	1.8	.0
Salt Lake City	4,360	86	210	25.81	30.29	+.14	35.0	+5.8	54	22	42	19	12	28	22	31	26	70	1.47	+.2	9	4,165	nw.	27	se.	1	6	11	14	6.5	6.8	.2
Grand Junction	4,602	60	68	25.52	30.19	+.13	34.6	+10.6	54	29	45	16	12	24	28	29	23	67	.41	-.2	4	3,911	nw.	25	s.	1	17	10	4	3.4	2.5	.0
Northern Plateau							38.3	+10.5										76	1.19	-0.5										7.2		
Baker	3,471	48	53	26.64	30.30	+.14	35.6	+10.7	53	26	43	20	11	28	23	33	30	80	.70	-.7	14	4,670	se.	24	sw.	23	8	8	15	6.5	.8	.0
Boise	2,739	79	87	27.40	30.33	+.14	39.8	+10.0	55	19	47	23	9	33	21	36	31	71	1.29	-.4	11	3,991	se.	18	se.	19	7	4	20	7.0	T	.0
Pocatello	4,477	60	68	25.65	30.29	+.09	34.1	+9.4	50	22	40	15	7	28	21	30	26	74	.73	-.7	9	6,701	se.	30	sw.	5	7	7	17	7.0	2.5	.0
Spokane	1,929	101	110	28.10	30.20	+.08	37.4	+9.9	53	27	43	24	18	32	22	35	32	82	2.57	+.4	16	5,756	s.	25	sw.	23	5	3	23	7.9	1.3	.0
Walla Walla	991	57	65	29.13	30.22	+.07	43.7	+11.0	63	27	50	28	9	37	27	40	35	73	1.21	-.8	14	4,862	s.	23	w.	23	5	6	20	7.6	.0	.0
Yakima	1,076	58	67	29.04	30.21	-----	39.2	+11.8	58	21	47	26	15	32	28	36	31	75	.63	-.7	9	3,323	nw.	25	sw.	21	6	7	18	6.9	.7	.0
North Pacific Coast Region							46.6	+5.9										85	7.19	+0.5										8.7		
North Head	211	11	56	29.94	30.17	+.12	47.2	+5.1	66	28	51	36	14	44	23	46	43	87	9.52	+.7	25	13,609	s.	60	s.	13	2	3	26	8.6	.0	.0
Seattle	125	90	321	30.02	30.15	+.10	45.6	+6.1	57	8	50	32	8	42	25	43	40	81	6.31	+1.4	23	8,763	s.	42	sw.	23	1	7	23	8.8	T	.0
Tatoosh Island	86	10	54	30.00	30.10	+.12	45.9	+4.7	60	8	49	37	15	43	14	44	42	89	14.17	+2.3	26	15,539	e	54	sw.	23	2	3	26	8.6	.0	.0
Medford	1,329	29	58	28.84	30.28	-----	41.4	-----	56	26	48	26	8	35	28	40	38	87	2.70	-.1	17	2,940	nw.	21	w.	19	0	8	23	8.7	T	.0
Portland, Oreg	153	68	106	30.06	30.22	+.14	46.9	+7.5	59	28	52	34	14	42	18	44	41	82	6.02	-.6	21	5,089	se.	24	sw.	20	3	2	26	8.5	.0	.0
Roseburg	510	45	76	29.70	30.26	+.16	47.2	+6.0	66	31	54	30	11	40	29	45	42	84	4.42	-.9	15	2,688	sw.	19	sw.	23	0	6	25	8.8	.0	.0
Middle Pacific Coast Region							50.0	+3.0										81	1.77	-3.3										5.7		
Eureka	62	73	89	30.20	30.27	+.17	50.8	+3.9	65	7	57	37	11	45	20	49	47	89	3.83	-3.3	14	4,298	se.	31	sw.	19	9	5	17	6.4	.0	.0
Red Bluff	330	5	58	29.89	30.25	+.13	49.8	+4.0	76	27	58	32	11	42	32	46	41	77	.88	-3.9	6	4,358	nw.	27	se.	1	12	4	15	5.5	.0	.0
Sacramento	66	87	115	30.17	30.24	+.12	47.8	+2.0	70	25	54	37	21	42	27	45	43	83	1.33	-2.4	4	4,823	se.	24	nw.	24	10	6	15	6.0	.0	.0
San Francisco	155	208	243	30.05	30.22	+.11	51.8	+1.9	72	25	57	40	10	46	20	48	43	76	1.03	-3.5	7	3,872	n.	23	w.	23	13	7	11	4.8	.0	.0
South Pacific Coast Region							54.2	+2.5										66	1.32	-1.0										3.5		
Fresno	327	97	105	29.89	30.26	+.16	46.0	-.2	70	27	53	32	8	39	28	43	40	82	.43	-1.3	5	3,054	nw.	19	nw.	23	7	9	15	6.6	.0	.0
Los Angeles	338	159	191	29.77	30.14	+.06	60.4	+5.8	80	16	71	44	8	50	28	49	38	51	3.22	+.1	2	4,097	ne.	22	nw.	24	25	5	1	1.5	.0	.0
San Diego	87	62	70	30.01	30.11	+.04	56.1	+1.8	74	9	65	42	15	47	27	49	42	65	.30	-1.8	1	3,869	nw.	24	e.	7	23	5	3	2.3	.0	.0
West Indies																																
San Juan	82	9	54	29.94	30.03	-----	74.8	-.2	83	21	80	65	30	70	14	-----	-----	-----	8.09	+3.9	24	8,691	e.	36	e.	7	6	22	3	5.1	.0	.0
Panama Canal																																
Balboa Heights	118	6	97	[1] 29.78	[1] 29.85	+.02	78.6	-1.3	89	10	86	69	29	71	19	-----	-----	[1] 81	4.04	+3.1	12	4,888	nw.	20	n.	22	0	26	5	5.9	.0	.0
Cristobal	36	6	97	[1] 29.85	[1] 29.88	+.02	80.2	-1.3	86	8	84	72	5	76	13	74	72	[1] 77	3.94	+.5	14	9,011	n.	25	ne.	21	10	19	2	4.8	.0	.0
Alaska																																
Fairbanks	454	11	87	[2] 29.29	[2] 29.90	-----	-3.2	-----	34	6	-23	-66	14	-39	45	-30	-33	85	.70	-----	6	1,867	nw.	18	s.	29	18	4	9	4.0	12.0	32.8
Juneau	80	11	50	[2] 29.53	[2] 29.62	-----	29.0	-----	48	28	34	-2	1	24	19	28	26	88	14.91	-----	31	6,320	se.	33	se.	8	0	1	30	9.8	63.7	4.8
Hawaiian Islands																																
Honolulu	38	86	100	[2] 29.99	[2] 30.03	-----	73.5	+2.6	80	3	78	66	23	69	13	67	65	76	2.24	-1.5	12	5,727	e.	30	ne.	31	12	13	6	4.7	.0	.0

[1] Observations taken bihourly.
[2] Pressure not reduced to mean of 24 hours.

TABLE 2.—*Data furnished by the Canadian Meteorological Service*

JANUARY 1934

Stations	Altitude above mean sea level, Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max.+mean min.÷2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*In.*	*In.*	*In.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*In.*	*In.*	*In.*
Cape Race, Newfoundland	99												
Sydney, Cape Breton Island	48	29.93	29.98	+0.05	15.6	−4.9	25.5	5.7	43	−15	3.39	−1.71	23.5
Halifax, Nova Scotia	88	29.72	29.83	−.14	20.0	−1.8	28.2	11.9	42	−10	2.93	−2.84	10.5
Yarmouth, Nova Scotia	65	29.89	29.97	−.03	23.8	−2.5	31.1	16.5	45	−1	3.35	−1.81	16.3
Charlottetown, Prince Edward Island	38	29.92	29.96	.00	14.0	−3.0	23.2	4.8	42	−13	3.03	−.93	29.0
Chatham, New Brunswick	28	29.87	29.91	−.06	8.1	−1.7	20.2	−4.0	40	−33	2.26	−1.33	17.9
Father Point, Quebec	20	29.98	30.01	+.03	7.8	−.2	16.2	−.7	36	−22	2.38	−.47	23.8
Quebec, Quebec	296	29.71	30.05	+.03	10.2	+1.1	17.4	3.0	36	−24	3.31	−.70	30.5
Doucet, Quebec	1,236				.7		14.2	−12.9	37	−50	2.37		23.5
Montreal, Quebec	187												
Ottawa, Ontario	236	29.80	30.09	+.06	14.0	+4.4	22.9	5.2	43	−25	2.69	−.30	22.3
Kingston, Ontario	285	29.74	30.08	+.03	20.0	+2.9	27.9	12.1	42	−15	2.08	−1.37	12.1
Toronto, Ontario	379	29.65	30.08	+.03	25.8	+4.4	32.6	19.0	43	−9	1.52	−1.40	4.0
Cochrane, Ontario	930				3.3		12.6	−6.0	37	−36	1.59		14.2
White River, Ontario	1,244	28.60	29.98	−.03	9.0	+9.4	19.5	−1.5	36	−42	3.82	+2.13	34.2
London, Ontario	808				25.5		32.0	18.9	42	−2	2.19		11.1
Southampton, Ontario	656	29.30	30.04	+.01	23.5	+3.1	29.1	17.9	42	−10	2.28	−1.77	20.1
Parry Sound, Ontario	688	29.31	30.04	+.03	17.9	+4.1	25.7	10.2	38	−20	1.46	−2.62	4.1
Port Arthur, Ontario	644	29.29	30.03	−.04	13.9	+10.8	21.4	6.5	38	−29	1.28	+.46	8.5
Winnipeg, Manitoba	760	29.17	30.05	−.06	5.8	+12.6	17.6	−5.9	39	−39	1.04	+.16	10.3
Minnedosa, Manitoba	1,690	28.14	30.06	−.04	6.9	+14.1	17.8	−4.0	39	−39	.81	+.01	8.1
Le Pas, Manitoba	860				−4.4		6.0	−14.7	36	−48	1.93		19.3
Qu'Appelle, Saskatchewan	2,115	27.62	29.96	−.12	12.9	+16.7	23.5	2.4	42	−24	.79	+.29	7.6
Moose Jaw, Saskatchewan	1,759				17.5		29.1	5.9	42	−21	.72		T
Swift Current, Saskatchewan	2,392	27.35	29.92	−.17	22.9	+19.8	33.0	12.8	46	−16	.60	+.05	5.5
Medicine Hat, Alberta	2,365	27.39	29.93	−.14	26.3	+20.8	36.7	15.8	50	−12	.61	+.04	.0
Calgary, Alberta	3,540	26.16	29.94	−.09	26.9	+18.5	38.0	15.9	54	−20	.22	−.31	.0
Banff, Alberta	4,521												
Prince Albert, Saskatchewan	1,450	29.38	30.03	−.06	12.7	+21.1	19.8	5.7	44	−37	.20	−.77	2.0
Battleford, Saskatchewan	1,592	28.18	30.01	−.07	10.0	+15.9	21.8	−1.8	43	−25	.35	−.05	3.4
Edmonton, Alberta	2,150												
Kamloops, British Columbia	1,262												
Victoria, British Columbia	230	29.86	30.12	+.15	43.5	+5.0	46.5	40.4	52	34	7.27	+1.88	.0
Barkerville, British Columbia	4,180												
Estevan Point, British Columbia	20												
Prince Rupert, British Columbia	170												
Hamilton, Bermuda	151	30.06	30.23	+.10	63.7	+1.7	68.4	59.1	75	49	4.86	−.08	.0

LATE REPORTS FOR DECEMBER 1933

Stations	Altitude	Station pressure	Sea level pressure	Departure from normal	Mean max.+mean min.÷2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
Cape Race, Newfoundland	99				24.2		31.8	16.6	46	−6	4.78		26.2
Montreal, Quebec	187	29.90	30.13	+0.10	10.8	−7.5	17.7	3.9	37	−29	4.41	+0.76	35.6
Swift Current, Saskatchewan	2,392	27.34	30.01	+.12	6.6	−9.4	16.0	−2.9	53	−22	1.51	+.73	15.1
Medicine Hat, Alberta	2,365												
Calgary, Alberta	3,540												
Banff, Alberta	4,521	25.10	29.95	+.01	6.6	−12.5	15.7	−2.6	44	−44	6.22	+5.01	61.8
Edmonton, Alberta	2,150	27.66	30.08	+.15	−9.7	−22.8	−4.6	−14.8	33	−36	2.85	+2.15	28.5
Kamloops, British Columbia	1,262	28.55	29.88	−.06	24.2	−4.7	30.3	18.1	51	−6	1.57	+.79	15.7
Estevan Point, British Columbia	20				42.1		46.7	37.5	51	29	19.38		T
Prince Rupert, British Columbia	170				25.7		30.0	21.5	47	8	4.86		16.3

SEVERE LOCAL STORMS, JANUARY 1934

[Compiled by Mary O. Souder]

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A revised list o tornadoes will appear in the Annual Report of the Chief of Bureau]

Place	Date	Time	Width of path (yards)	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Los Angeles, Calif., and vicinity.	1			38		Torrential rain and flood.	60 persons missing; bridge on the Los Angeles-Glendale highway collapsed.	Official, U.S. Weather Bureau.
Concordia, Kans	2					Sleet and glaze	Traffic considerably retarded for about 2 days	Do.
Port Arthur (near) Tex	3	3-4 p.m	100		$25,000	Tornado	2 persons injured; buildings and fences damaged	Do.
Pensacola, Fla., 7 miles southwest.	4	6:35 a.m				Tornado and rain	Only damage reported was the unroofing of a filling station on the Mobile highway about 11 miles west of the city.	Do.
Pensacola, Fla., near Naval Air Station.	4	Noon	17-34			do	Garage destroyed	Do.
Pensacola, Fla., 3 miles south-southwest.	4	12:07-12:15 p.m.	33-200	1	30,000	do	This tornado formed over Pensacola Bay and moved inland; child fatally injured and 7 others suffered minor injuries; $10,000 damage to Bruce Dry Dock Co.; power lines blown down; lumber from the Walker Lumber Co. scattered in all directions; small frame buildings completely destroyed.	Do.
Hobson, Mont	5	A.m				Wind	Barn completely demolished; dwelling and 2 other buildings damaged.	Do.
Pana, Ill	12				500	do	Buildings damaged	Do.
Northern New England	14-15					Snow	Outlying districts isolated; automobile traffic impossible in some districts; wires down and trees damaged; record fall of 25 inches in Burlington, Vt.; 14 inches of snow fell at Rutland, Vt.	Do.
Edwardsville, Monmouth, Springfield, and Windsor, Ill.	28				500	Wind	Damage to wires, roofs, trees, and windows; $500 estimated for Springfield alone.	Do.
Indianapolis, Ind	28					Gale	Wires, poles, signs, chimneys, and trees blown down; large plate glass window blown in.	Do.
Pittsburgh, Pa	28					Gale, sleet, and snow.	Traffic greatly impeded; only 1 airplane arrived at the municipal airport during the day.	Do.
Cleveland, Ohio	28-29					Gale	Number of plate glass windows in downtown buildings broken; anemometer registered a maximum velocity of 60 miles, the highest ever recorded at this station; extreme velocity 71 miles.	Do.
New York City, N.Y	28-29					do	Wind of 57 miles per hour attending a cold wave intensified the suffering among the poor and caused some damage to property.	Do.
South Dakota, entire State	31	7 a.m.-7 p.m.				Wind and dust	Due to long-continued drought and barren fields, high winds caused blowing of soil that injured winter rye; much labor and expense involved in cleaning up after the storm.	Do.

SEVERE LOCAL STORMS, DECEMBER 1933 (SUPPLEMENTARY TABLE)

Place	Date	Time	Width of path (yards)	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Montague, Mont	21	2 a.m.			$1,500	Wind	Damage to 2 buildings in center of group of buildings, haystacks, and wagons.	Official, U.S. Weather Bureau.
Hobson, Mont., 2 miles west	27		7			Tornadic winds	Barn demolished	Do.

Chart I. Departure (°F.) of the Mean Temperature from the Normal, January 1934

Chart I. Departure (°F.) of the Mean Temperature from the Normal, January 1934

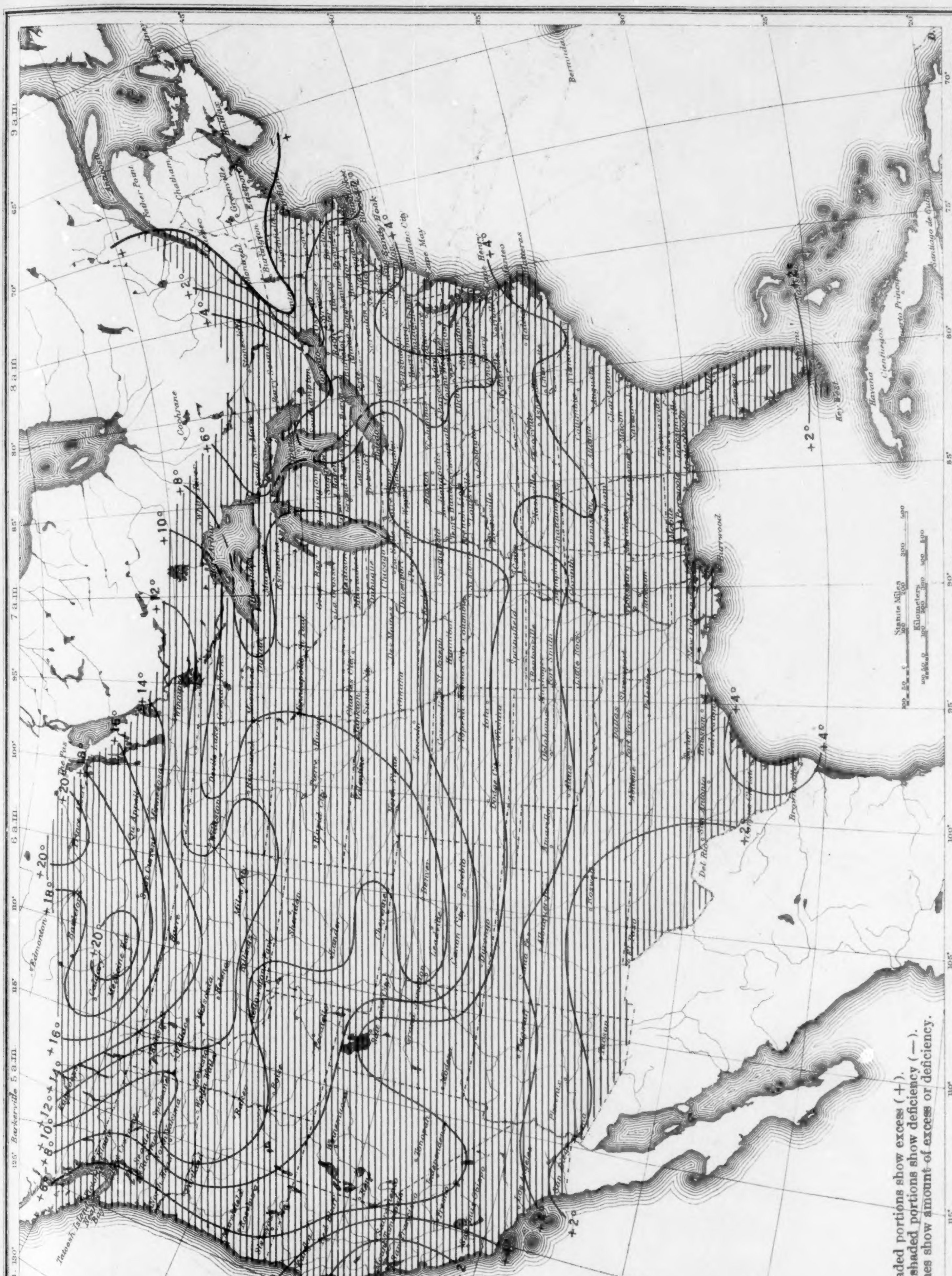
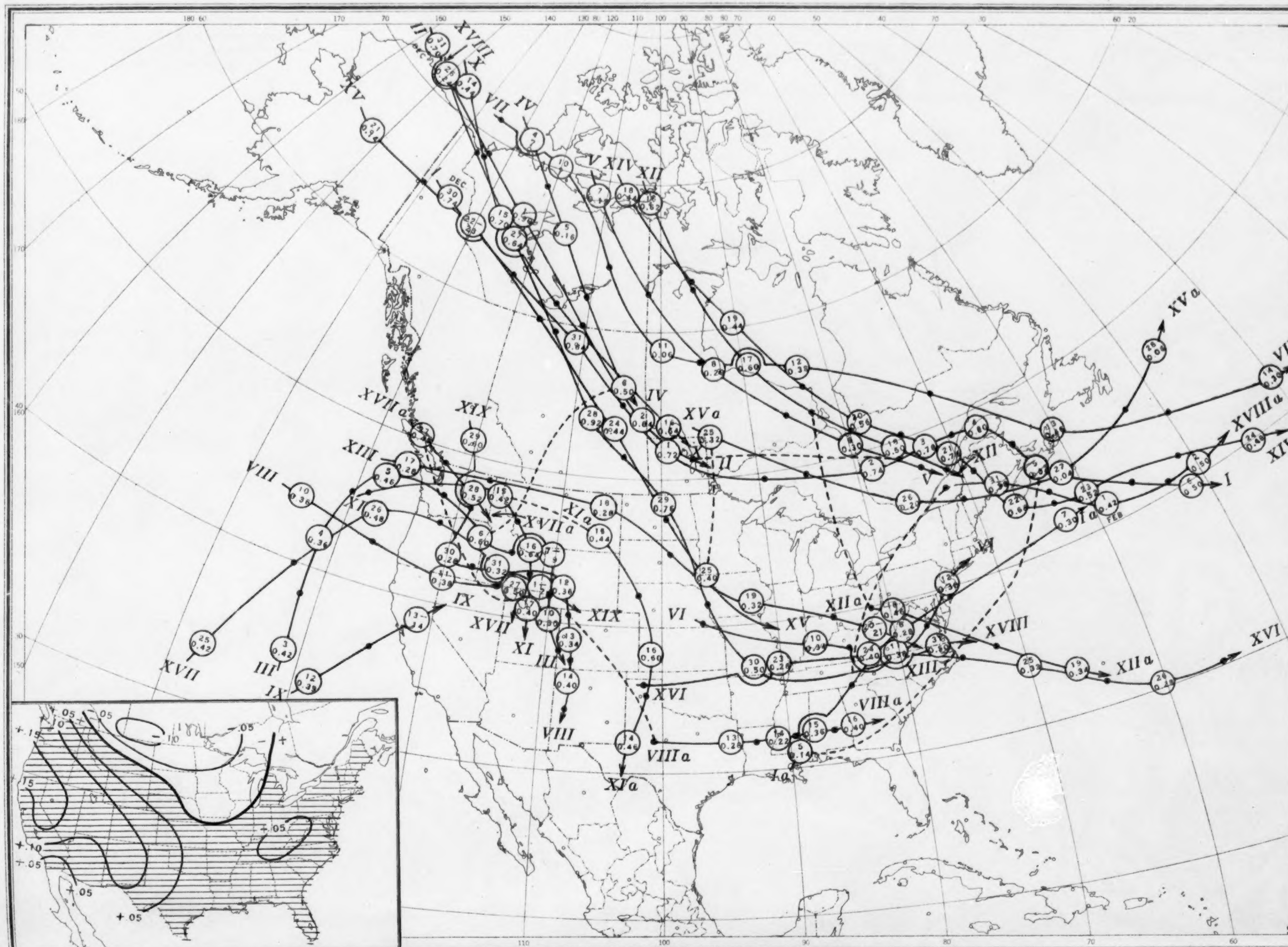


Chart II. Tracks of Centers of Anticyclones, January 1934. (Inset) Departure of Monthly Mean Pressure from Normal

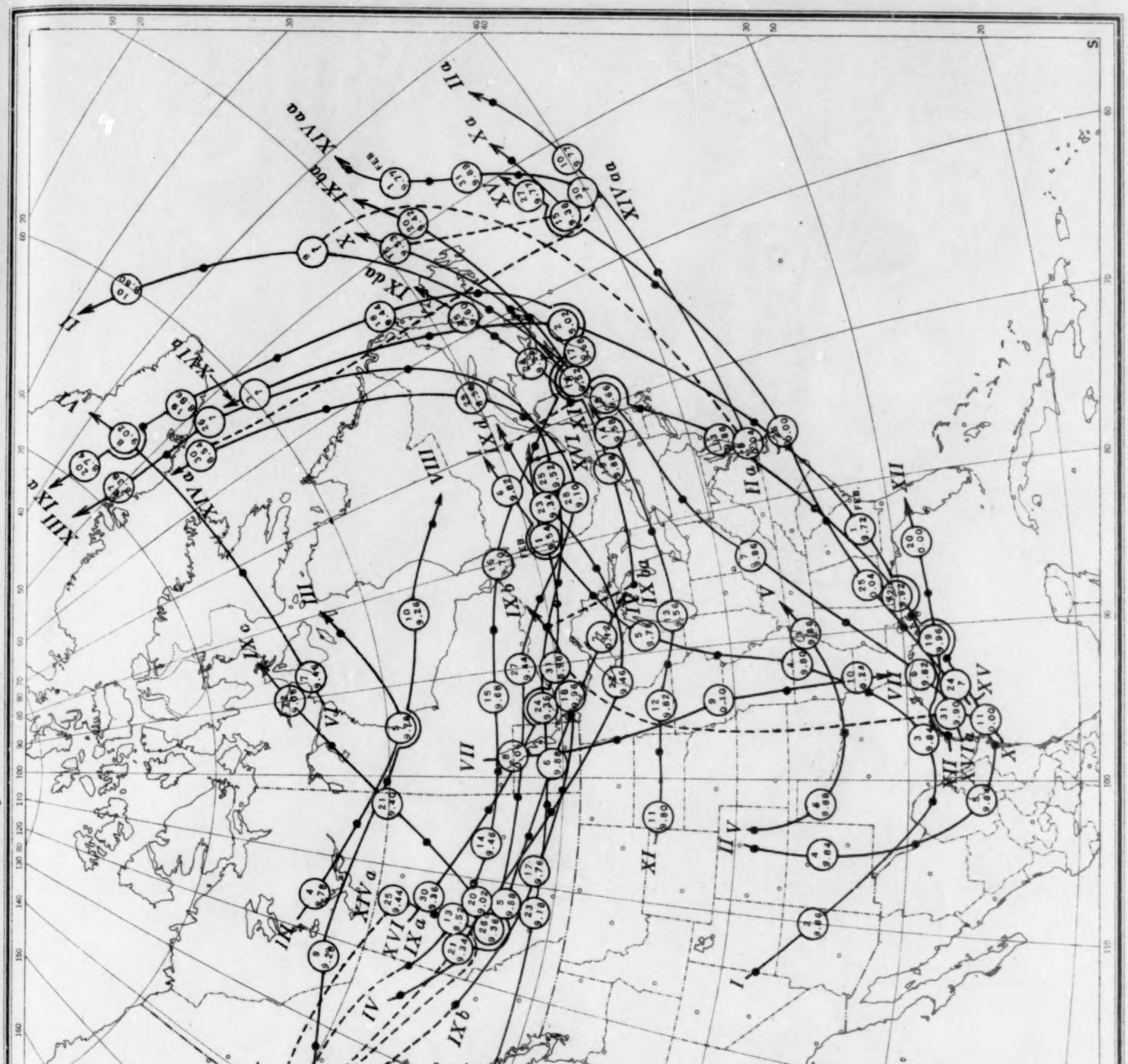
(Plotted by W. R. Stevens)



Circle indicates position of anticyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 8 p. m. (75th meridian time).

Chart III. Tracks of Centers of Cyclones, January 1934. (Inset) Change in Mean Pressure from Preceding Month

(Plotted by W. R. Stevens)



Circle indicates position of cyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 8 p. m. (75th meridian time).

Chart IV. Percentage of Clear Sky between Sunrise and Sunset, January 1934

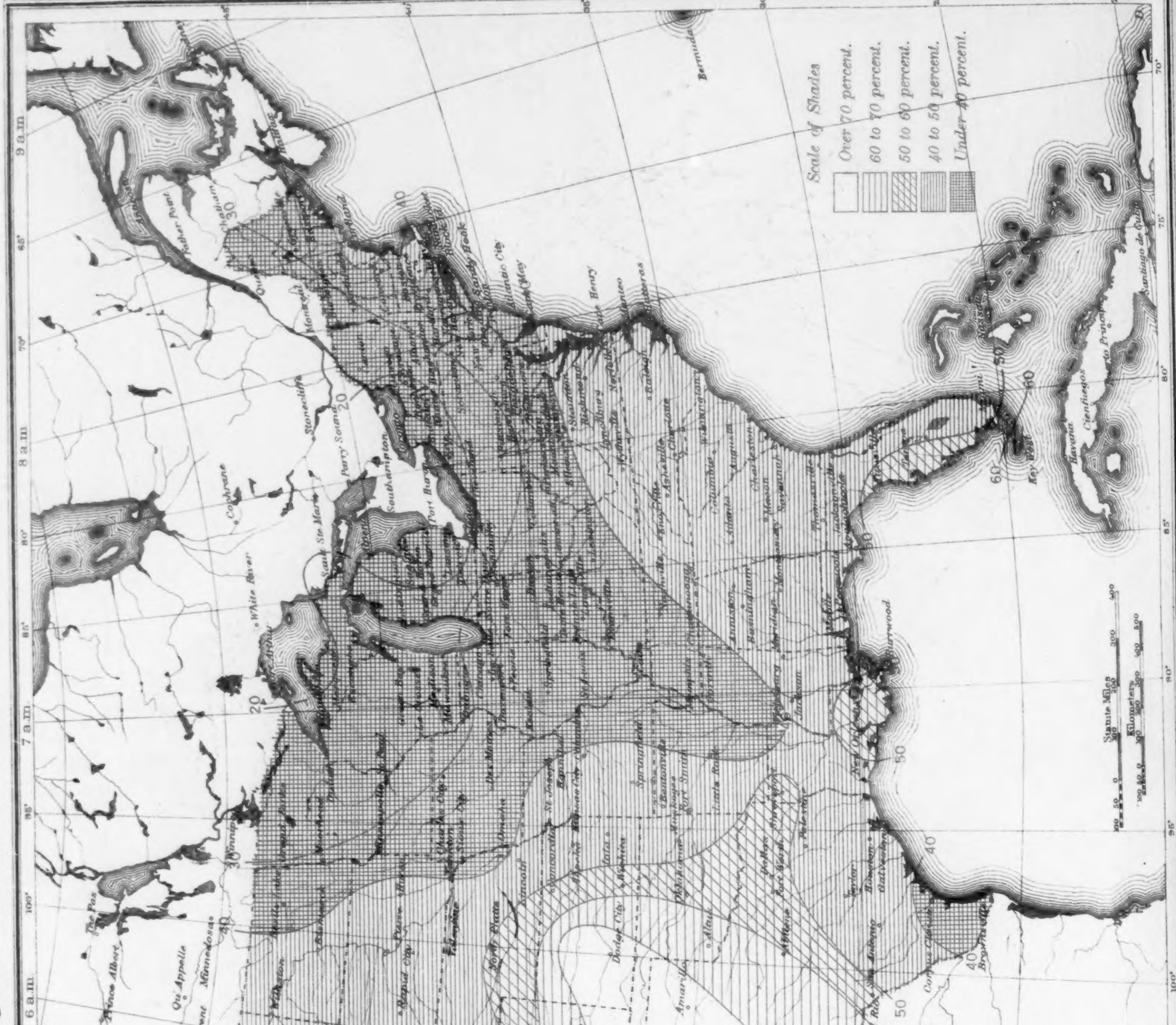


Chart V. Total Precipitation, Inches, January 1934. (Inset) Departure of Precipitation from Normal

Chart V. Total Precipitation, Inches, January 1934. (Inset) Departure of Precipitation from Normal

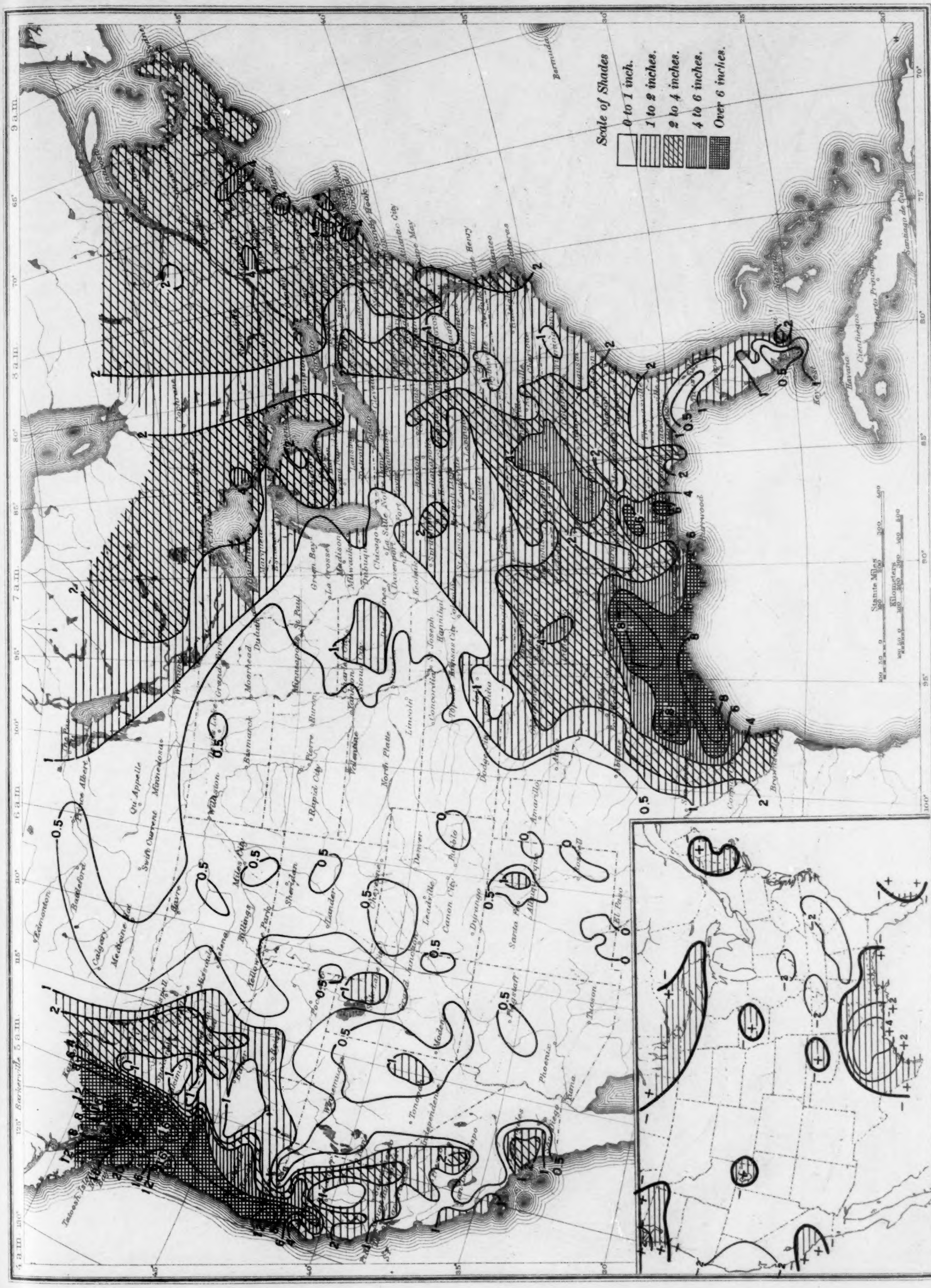


Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, January 1934

Chart VII. Total Snowfall, Inches, January 1934. (Inset) Depth of Snow on Ground at 8 p. m., Monday, January 29, 1934

Chart VII. Total Snowfall, Inches, January 1934. (Inset) Depth of Snow on Ground at 8 p. m., Monday, January 29, 1934

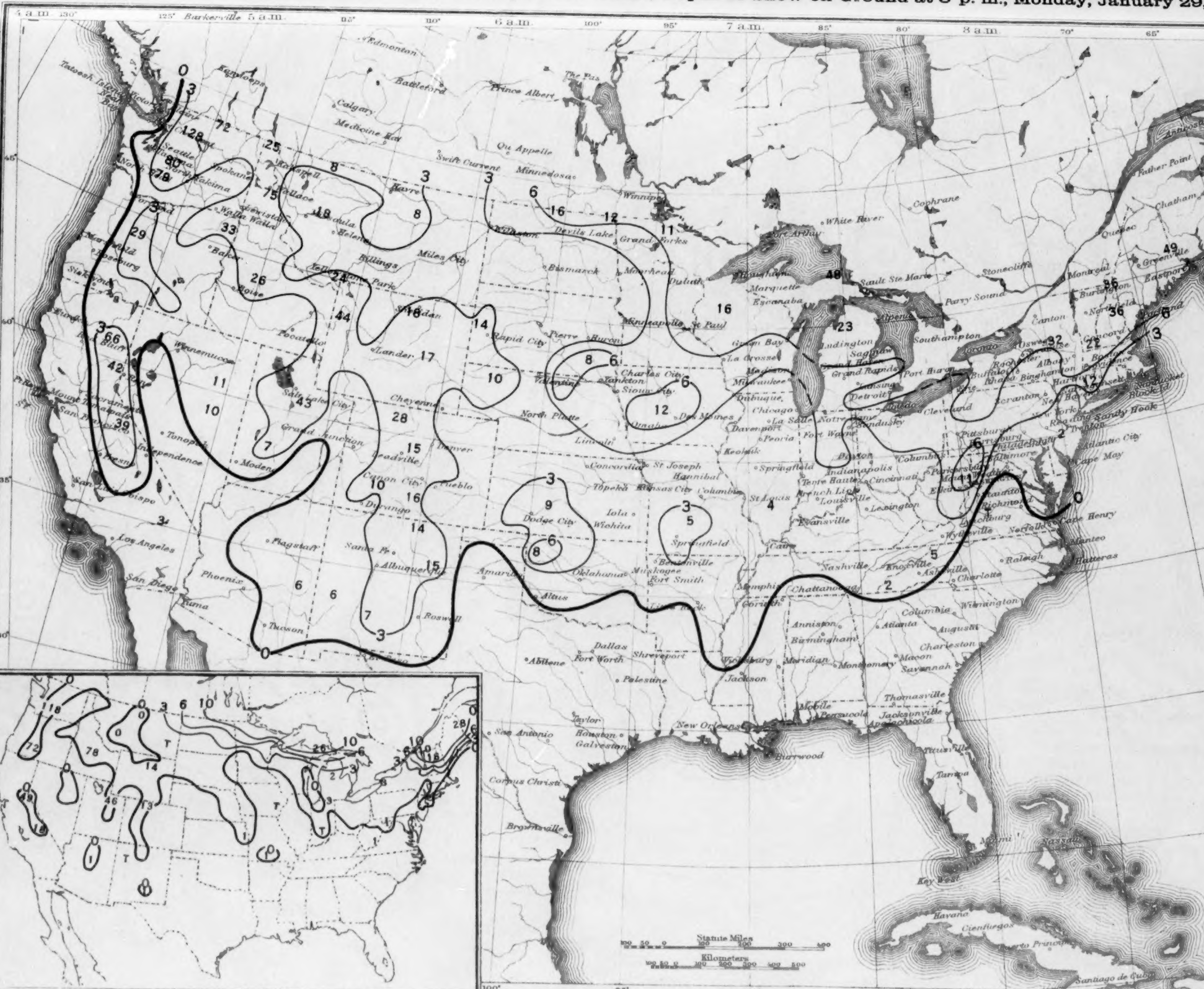
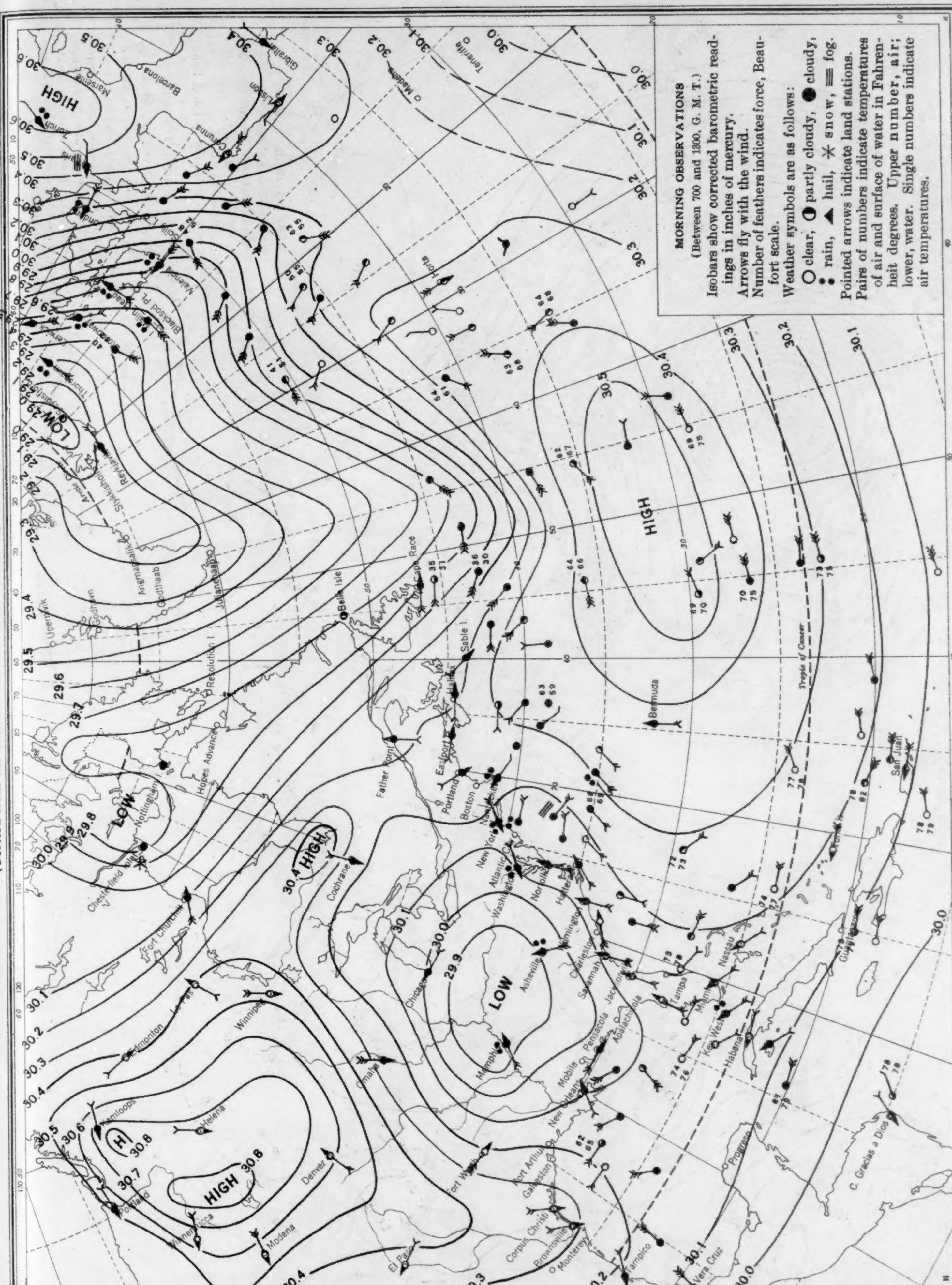


Chart VIII. Weather Map of North Atlantic Ocean, January 7, 1934
(Plotted from the Weather Bureau Northern Hemisphere Chart)

Chart VIII. Weather Map of North Atlantic Ocean, January 7, 1934
(Plotted from the Weather Bureau Northern Hemisphere Chart)



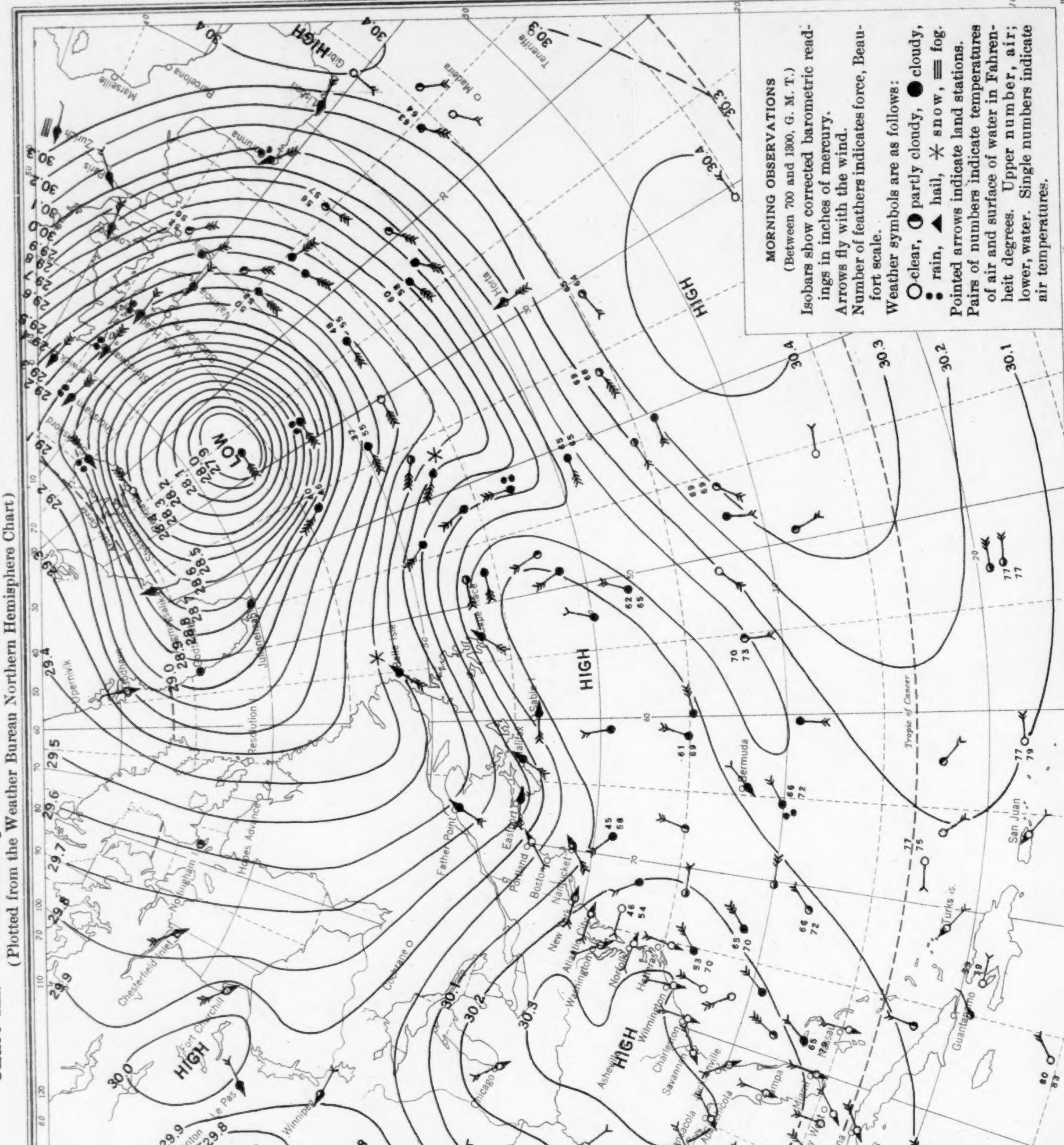


Chart IX. Weather Map of North Atlantic Ocean, January 11, 1934
(Plotted from the Weather Bureau Northern Hemisphere Chart)